
PIPE DESIGN

This video is the catastrophic failure of a culvert and then the roadway due excessive high headwater at the inlet. I think this is about an 8-foot diameter CSP, with over 8-feet of fill above it, and without edge protections and without cutoff walls. Due to the height of the water above the culvert the water is being sucked down into and through the culvert at high velocities. This causes a vacuum bubble to develop in the culvert top; and with that the culvert wants to violently float up to the surface. Please notice the debris coming in from the right side of the screen, then how it starts blocking the inlet.

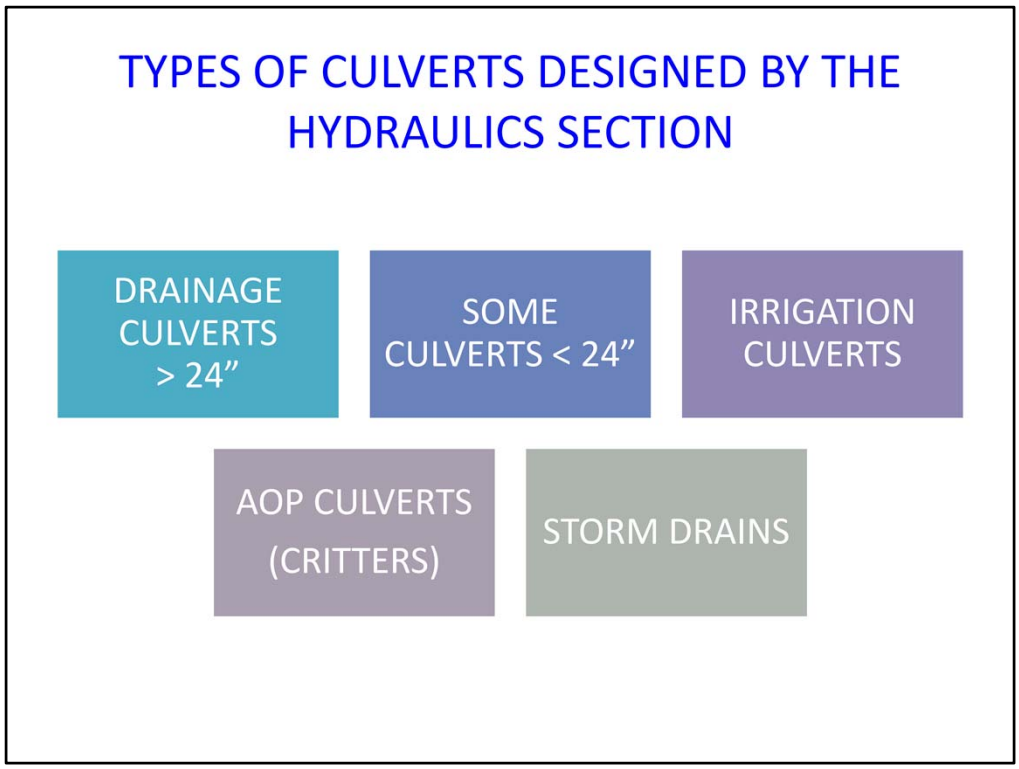
The high headwater is also forcing the water through the subgrade; eroding it away from around the culvert. The culvert is still inplace, but the material around it going fast. Soon the material around the culvert will all be gone and the culvert will eventually pop up like a beach ball. Watch for the sudden drop in the water surface elevation; the subgrade is going, going, and gone.

This illustrates what happens when something is missed or wrong in the

culvert design process. What was missed in the culvert design? To me the two main problems were the excessive high headwater (Allowable Headwater Elevation was exceeded) and there was no Concrete Edge Protection or Cut off wall included to prevent piping and erosion around the culvert? It's our job is prevent this from happening through comprehensive design, plans, and construction.

My name is Dave Leitheiser; I've been with MDT for almost 25-years and the Billings District Hydraulic Engineer for about 18-years. This session is the 'Culvert Design' presentation. The intent of my short presentation is to provide you with a brief background in the culvert hydraulic design and recommendation process. Then Louise Stoner follows with a presentation on the very technical process getting those recommendations into the construction plans.

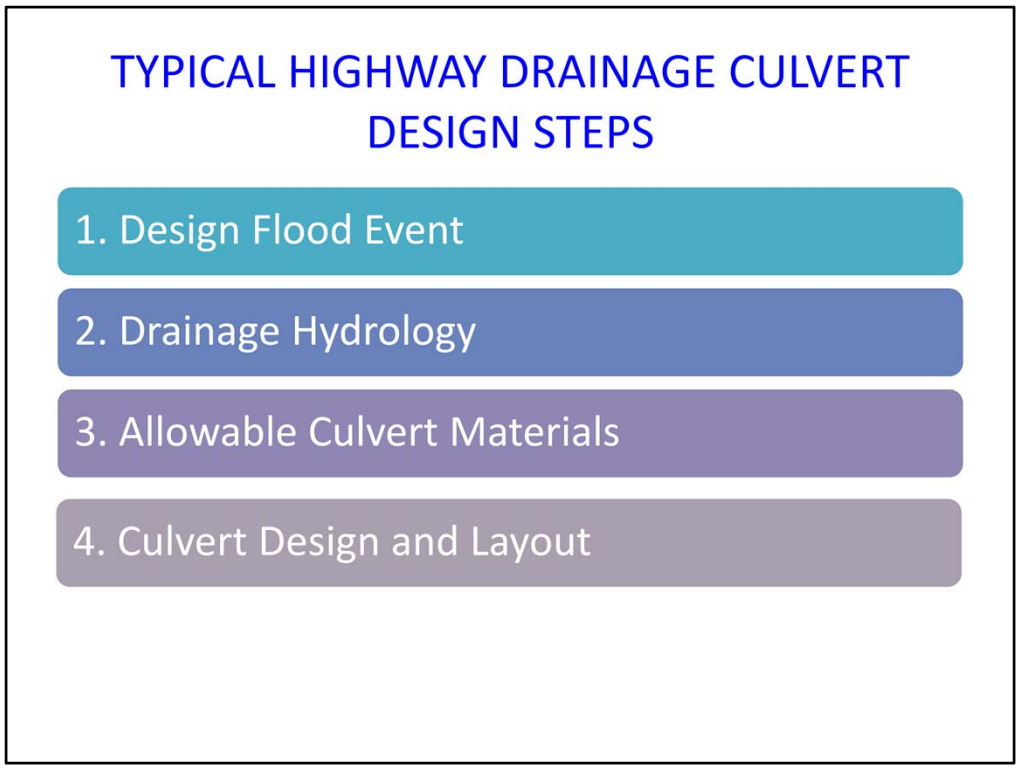
An important hydraulic design aspect at each drainage crossing is the Risk Assessments. This includes asking what the existing and post-construction risks are (such risks as loss of life, property damages, roadway overtopping or loss, interruption of emergency services, etc.), then the risks are compared to the economic costs of accepting or addressing those risks. The Hydraulics section's responsibility is to weigh the risks and develop recommendations for the drainage crossings. But which culverts does Hydraulics design?



Hydraulics is involved with several different types of culvert crossings:

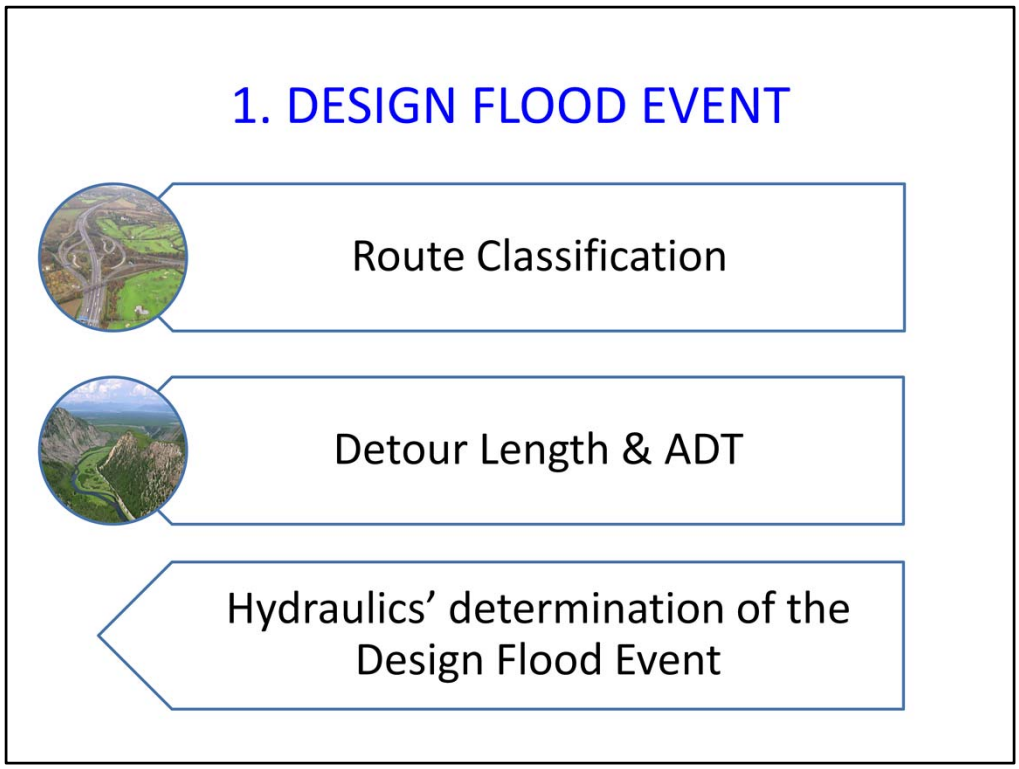
- **All drainage culverts larger than 24”** are hydraulically designed.
- The **Road Designer** is typically responsible for putting the **minimum size 24”cross drains** and smaller approach culverts in the plans package. However, in some cases it necessary for the 24” culverts and approach culverts be hydraulically designed. Such as if an existing minimum size cross culvert has had past performance issues, then Hydraulics section will typically be involved.
- All **irrigation structures and culverts** are hydraulically designed.
- AOP = **Aquatic Organism Passage (critter crossings)** are hydraulically designed in junction with Environmental Services consultation.
- All **Storm Drains** are hydraulically designed

My presentation is focused on hydraulically designed drainage culverts. So what are the typical steps in the design of a drainage culvert?



The typical Hydraulic Design of a highway drainage culvert involves many factors but there are a few key steps:

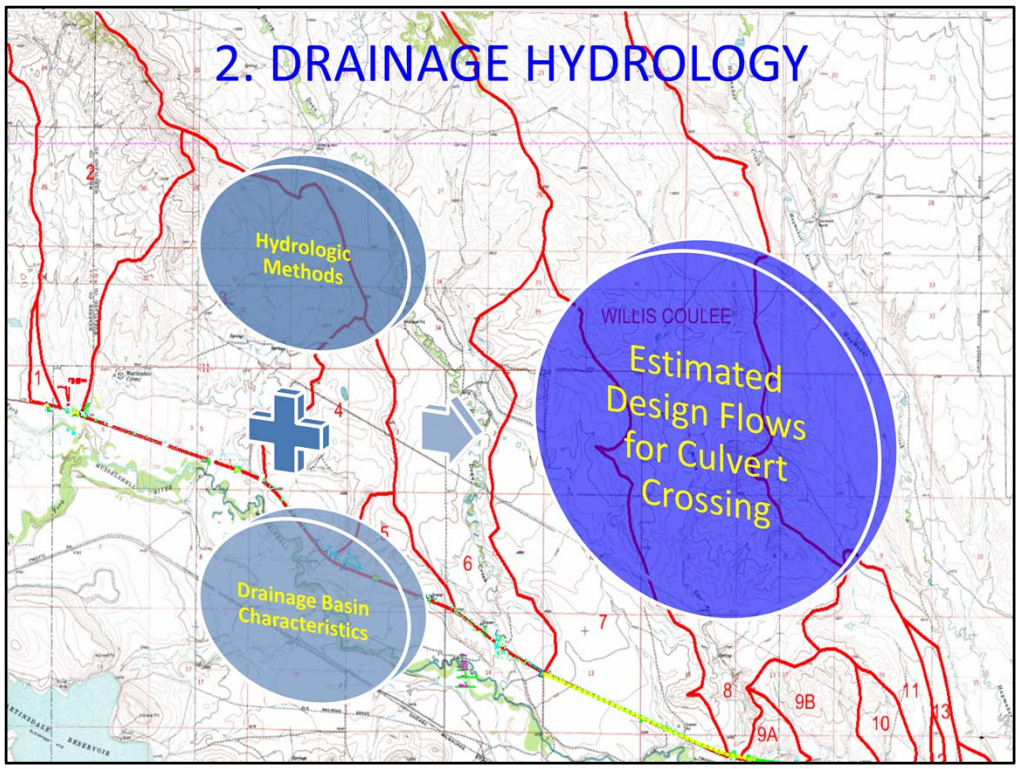
1. Determine the appropriate **Design Flood Event** for the crossing drainage per MDT criteria.
2. Determine the appropriate **Drainage Hydrology** to estimated the magnitude of the runoff for the Design Flood Event. Which of the many hydrologic method is the best predicts the volume of runoff actually making it to the crossing?
3. Then **Allowable Culvert Materials** are based on corrosivity results and/or available fill heights. Do we recommend culverts made of metal, concrete, or both?
4. The **Culvert Design and Layout** are the culmination of the design.



The Design Flood Event is the flood event that can be passed through the roadway without interruption of service, i.e. no overtopping of the roadway. Route Classifications: Interstate/Primary routes (50-yr), Secondary/certain urban routes (50 & 25-yr), and local/county routes (~10yr).

The ADT is provided by Traffic. Detour Length is the distance between two logical terminus on a similar or higher classified route.

The suggested Design Flood Event is found in the ADT & ADT X Detour Length Table provides. Hydraulics makes the determination which can be greater or less based on site and conditions. Such as a route with a 10-yr Design Flood can be raised to a 25-yr if emergency vehicles use the route.



The Drainage Hydrology is the estimated runoff flows at the individual culvert crossings determined with the selected Hydrologic Methods. The Hydrologic Methods are based on the varied Basin Characteristics, and in Montana the Basin Characteristics vary greatly from the western mountains to the eastern plains.

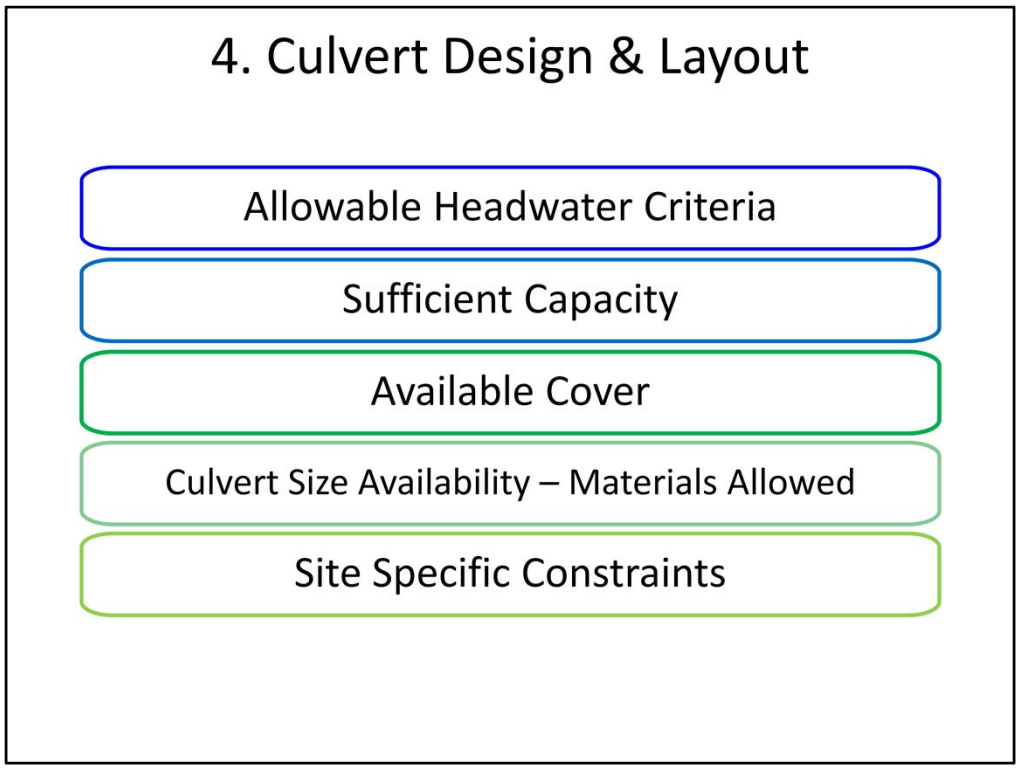
Some of the Drainage Basin Characteristics that are used in the Hydrologic Methods include: Basin Area, Average Elevation of the overall basin
% Area > 6000-ft in elevation, % Area covered by Forest, Mean Annual Precipitation, etc.

An excellent source of information in the development of the of the Drainage Hydrology are discussions with MDT Maintenance personnel and local residents. These discussions can reveal the past performance of existing pipes and historical flood event elevations to provide a calibration for estimated flows and culvert analysis results. The Hydrologic Method is usually applied to the entire project, but other methods may be used as needed to match conditions.

Geotechnical will take cores at major culvert crossings to determine if the in-situ soils are capable of supporting new pipes or if foundation treatment is needed.

Early in the project design process soil and water samples are taken by **Materials** to conduct the **corrosivity tests that are necessary for pipe material selections**. These soil and water samples are tested for their different characteristics such as pH/Marble pH, conductivity, and Sulfate content.

This is an important step in the culvert design for the determination of which culvert materials (metal and/or concrete) are acceptable and that will meet or exceed the Culvert Service Life. The Culvert Service Life for new mainline culverts is 75-years and varies for culverts being considered for remaining inplace. There are several other factors in developing the Culvert Service Life; these include the thickness of the metal culverts, coating of the metal culvers, and concrete pipe cement type.

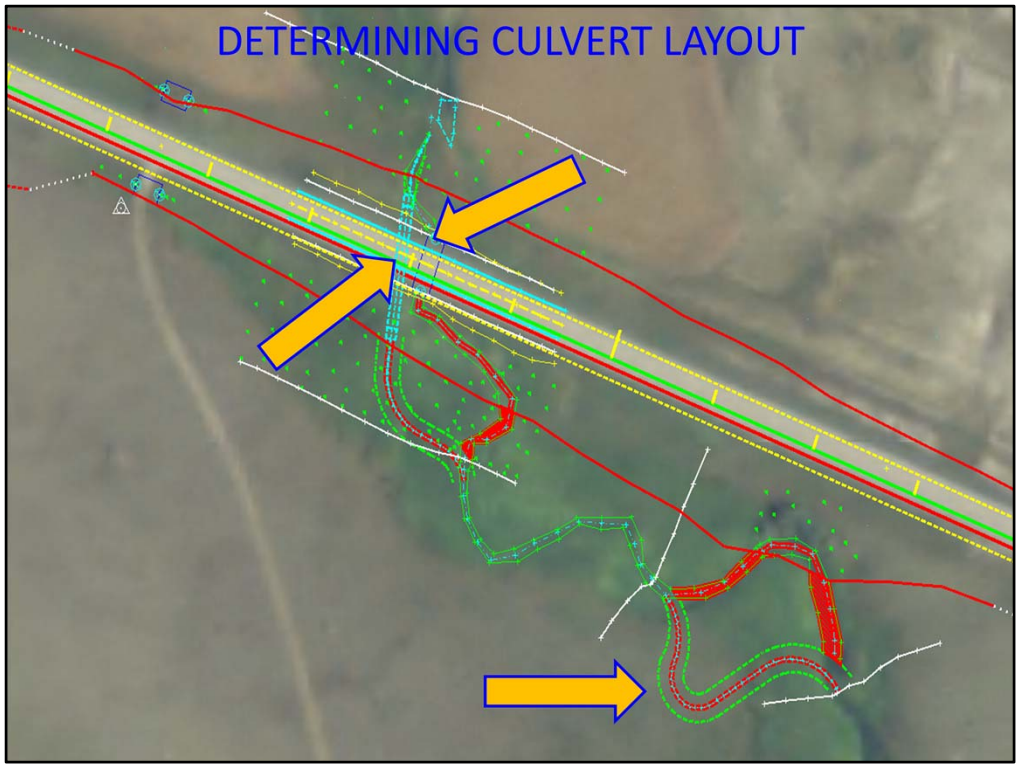


Now **Photogrammetry and Survey has** provided the necessary hydraulic survey, and **Road Design** provides the initial new roadway vertical/horizontal alignment and construction limits in their stripmap and cross-sections.

Now the back and forth process of culvert design and layout can begin. First some of the Culvert Design factors:

1. Site Specific Constraints – These factors site-by-site such as a history of flash floods, a home immediately upstream of the crossing, a delineated floodplain, etc.
2. Culvert Size Availability/Allowable Materials – Maximum sizes are 84” for RCP, 120” for CSP, 72” for CAP, SSPP over 120”, RCB sizes vary. Use the corrosive soil results to determine allowable materials.
3. Available Cover – Exceed the depth of cover from the top of the culvert to the bottom of flexible pavement or top of rigid pavement. CSP can be in a very deep fill where RCP cannot.
4. Sufficient Pipe Capacity – Can the pipe pass the design flows and still meet other design criteria and site specific constraints.

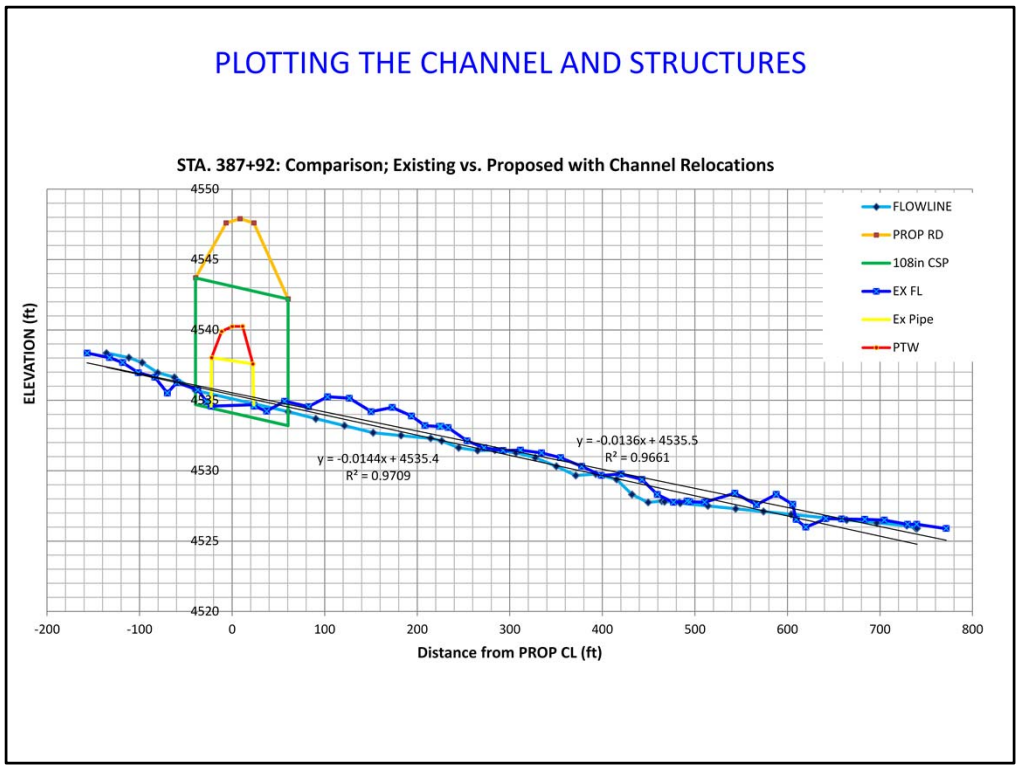
5. Allowable Headwater Criteria – A proposed size is analyzed based on the above information for the design flood and the 100-year flood. If the proposed culvert causes too high of a headwater then a larger culvert or other structures is likely needed to lower the headwater.



The next part of the back & forth is setting the proposed culvert in the channel with respect to the culvert design parameters and site conditions. For brevity what we see here is finished design with the existing channel, existing culvert, the proposed culvert, and channel changes.

You can see that due to our roadway widening and flatter roadway slopes we will have two separate channel changes for the drainage channel downstream of the new pipe. You'll notice the channel changes are pretty much mirror images of the channels being obliterated with the construction limits. This is to keep the approximate pre and post-channel lengths equal. This good for the critters and stream stability by maintaining existing channel velocities.

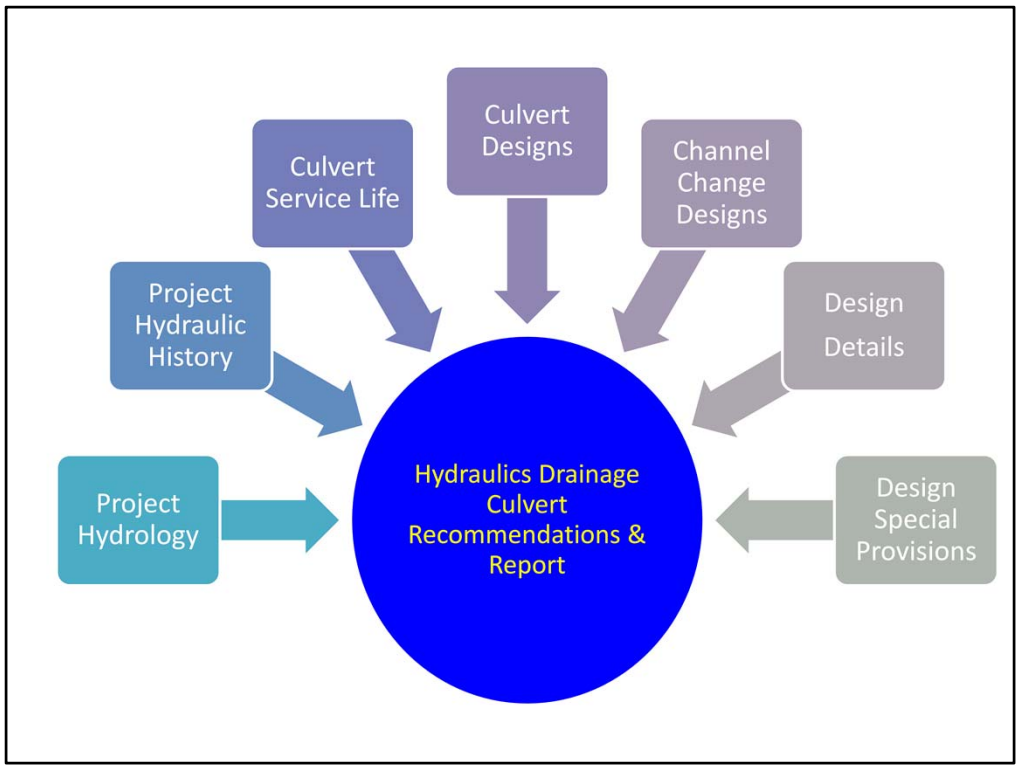
How we got to this point was with the aid of the cross-section, stripmap, and a spreadsheet graph of the channel and the structures.



Here is the spreadsheet with

1. The surveyed channel in dark blue from upstream to downstream,
2. the existing culvert and road in yellow and red,
3. the new channel with channel changes in light blue from upstream to downstream,
4. the new culvert and road in green and orange,
5. and the approximate channel profile in black.

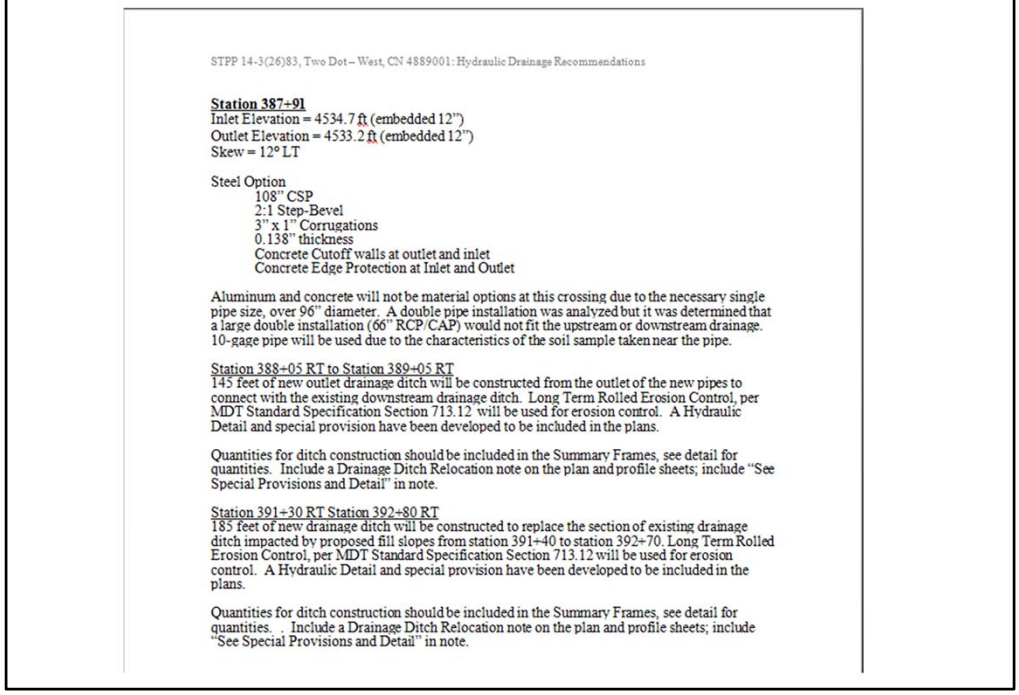
This allows us to estimate the average drainage slope, which in turn helps to design the appropriate pipe inverts (or flow lines). By placing the new pipe at the approximate slope of the existing drainage we greatly reduce the chance that the drainage needing to reestablish an equilibrium, i.e. forming a head-cut to adjust the channel slope after the new pipe is installed.



Here is a quick rundown of all the different types of information that you may find included in Hydraulics Drainage Recommendations and Reports

1. Project Hydrology –
2. Project Hydraulic History –
3. Culvert Service Life –
4. Culvert Designs –
5. Channel Change Designs –
6. Design Details –
7. Design Special Provisions –

EXAMPLE CULVERT RECOMMENDATION



STPP 14-3(26)83, Two Dot – West, CN 4889001: Hydraulic Drainage Recommendations

Station 387+91
Inlet Elevation = 4534.7 ft (embedded 12")
Outlet Elevation = 4533.2 ft (embedded 12")
Skew = 12° LT

Steel Option
- 108" CSP
- 2:1 Step-Bevel
- 3" x 1" Corrugations
- 0.138" thickness
- Concrete Cutoff walls at outlet and inlet
- Concrete Edge Protection at Inlet and Outlet

Aluminum and concrete will not be material options at this crossing due to the necessary single pipe size, over 96" diameter. A double pipe installation was analyzed but it was determined that a large double installation (66" RCP/CAP) would not fit the upstream or downstream drainage. 10-gage pipe will be used due to the characteristics of the soil sample taken near the pipe.

Station 388+05 RT to Station 389+05 RT
145 feet of new outlet drainage ditch will be constructed from the outlet of the new pipes to connect with the existing downstream drainage ditch. Long Term Rolled Erosion Control, per MDT Standard Specification Section 713.12 will be used for erosion control. A Hydraulic Detail and special provision have been developed to be included in the plans.

Quantities for ditch construction should be included in the Summary Frames, see detail for quantities. Include a Drainage Ditch Relocation note on the plan and profile sheets; include "See Special Provisions and Detail" in note.

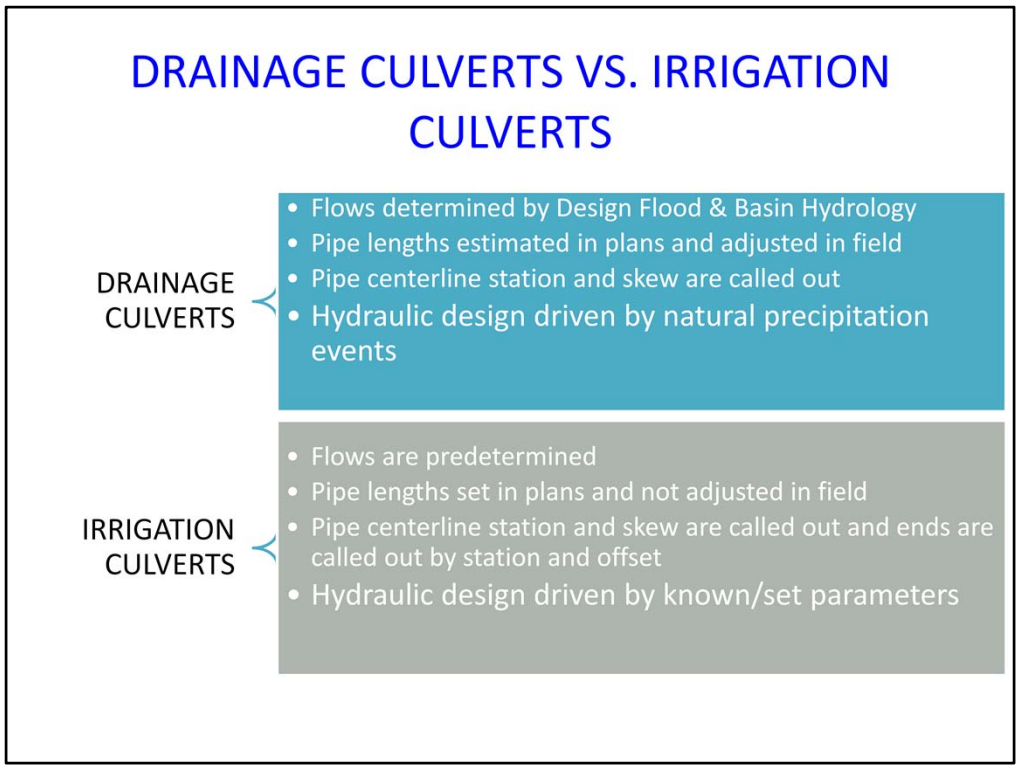
Station 391+30 RT Station 392+80 RT
185 feet of new drainage ditch will be constructed to replace the section of existing drainage ditch impacted by proposed fill slopes from station 391+40 to station 392+70. Long Term Rolled Erosion Control, per MDT Standard Specification Section 713.12 will be used for erosion control. A Hydraulic Detail and special provision have been developed to be included in the plans.

Quantities for ditch construction should be included in the Summary Frames, see detail for quantities. Include a Drainage Ditch Relocation note on the plan and profile sheets; include "See Special Provisions and Detail" in note.

This is an example of what a typical drainage pipe recommendation may look like. You will see the station of the proposed pipe crossing as well as pipe invert (or flowline) elevations and a pipe skew, pipe sizes based on pipe material, pipe thickness or class, the appropriate corrugations for metal pipe, and the appropriate end-treatments.

At times not all pipe materials are allowable. If this is the case you will often find a brief explanation as to why certain materials were excluded.

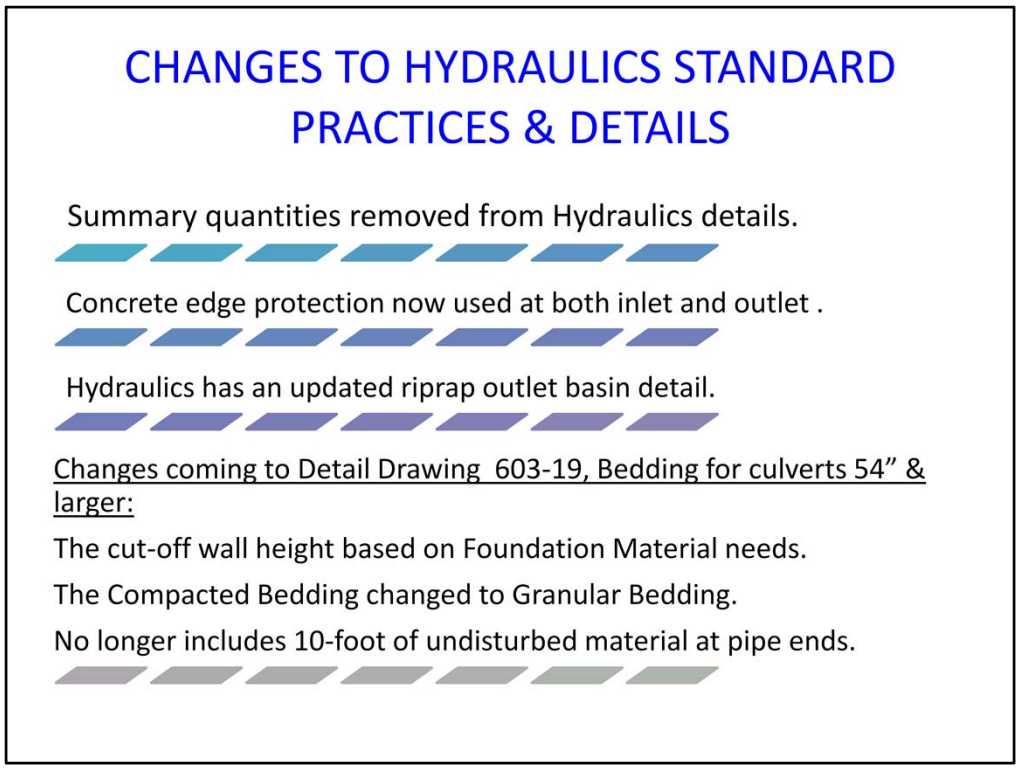
In addition to the new pipe recommendation you may also encounter a brief discussion of any channel changes that involve the drainage crossing. The discussion will likely included what type of callouts need to be included in the plans as well as where to find necessary quantities to be included in the plan summaries. Another piece of information that is typically included in the pipe recommendation if applicable is the name of hydraulics details that involve the pipe and need to be included in the plan set.



The other major type of culverts that are often found along projects are Irrigation culverts. Irrigation culverts and ditches carry water that is dedicated for agricultural or livestock purposes. When discussing irrigation designs with landowners you may often hear the saying, “waters for fighting, whiskey’s for drinking”. That’s because the water is a lifeline for many ranchers and farmers.

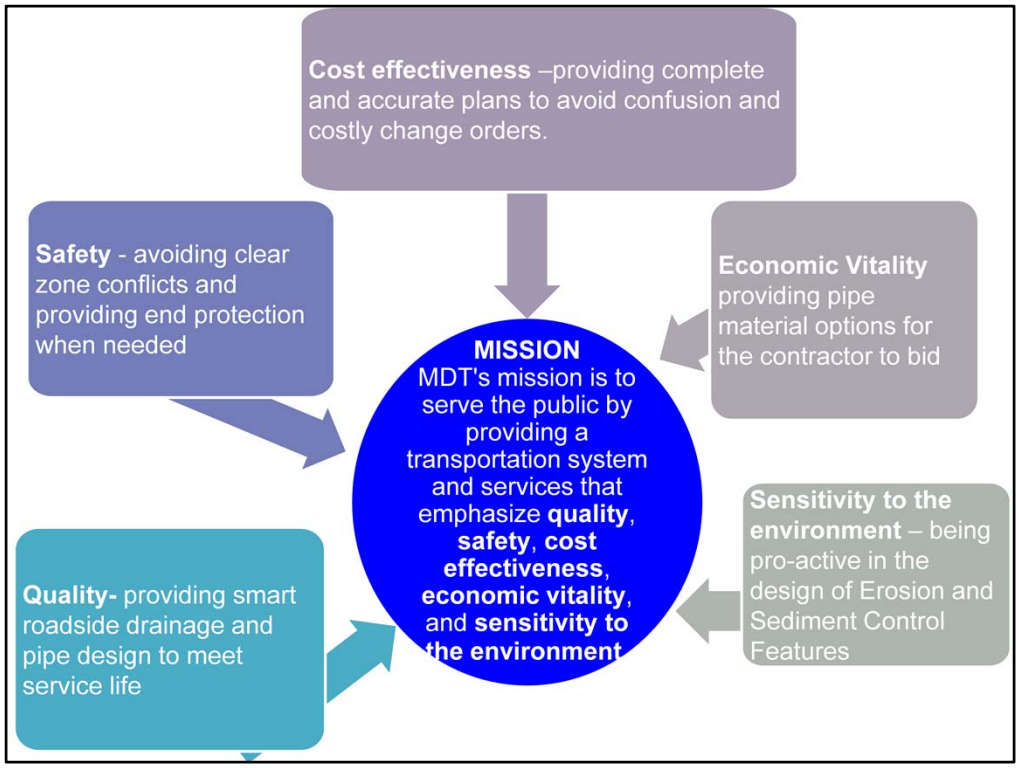
There are some key differences in the culvert information that is placed in the plans for irrigation culverts vs. drainage culverts.

1. Typically the inlet and outlet of irrigation culverts are outside of the highway R/W. On larger culverts the ends may be inside the R/W with the fencing warped to put the ends outside the fence.
2. Typically flows for irrigation culverts are known or set by decree .
3. Irrigation culverts typically have fairly exact end locations and elevations; not only should a flow line elevation be given but a station and offset for the culvert end should also be included.
4. Irrigation culvert locations, ends, skew, end elevations, etc will not typically be adjusted in the field as drainage culverts may be.



There changes to Hydraulics callouts and details.

Now we will discuss how existing and proposed pipes are put into the plans package, as well as how roadside drainage should be assessed and designed.


Cost effectiveness –providing complete and accurate plans to avoid confusion and costly change orders.
Safety - avoiding clear zone conflicts and providing end protection when needed
Economic Vitality providing pipe material options for the contractor to bid
MISSION
MDT's mission is to serve the public by providing a transportation system and services that emphasize **quality**, **safety**, **cost effectiveness**, **economic vitality**, and **sensitivity to the environment**
Sensitivity to the environment – being pro-active in the design of Erosion and Sediment Control Features
Quality- providing smart roadside drainage and pipe design to meet service life

TOPICS - Part One

- Existing Pipes
- Roadside Drainage
- New Culverts
- Clear Zones

Plan Abbreviations for pipes

- C.A.P. Corrugated Aluminum Pipe
- C.M.P. Corrugated Metal Pipe
- C.S.P. Corrugated Steel Pipe
- C.S.P.A. Corrugated Steel Pipe Arch
- CULV. Culvert
- DR. Drain
- H.D.P.E. High Density Polyethylene Pipes
- R.C.B. Reinforced Concrete Box
- R.C.P. Reinforced Concrete Pipe
- R.C.P.A. Reinforced Concrete Pipe Arch
- S.S.P.P. Structural Steel Plate Pipe
- S.S.P.P.A. Structural Steel Plate Pipe Arch Culvert
- S.S.P.C. Smooth Steel Casing Pipe

These are the common plan abbreviations for pipes. The most common are the C.S.P. Corrugated Steel Pipe and R.C.P. Reinforced Concrete Pipe

Existing Culverts

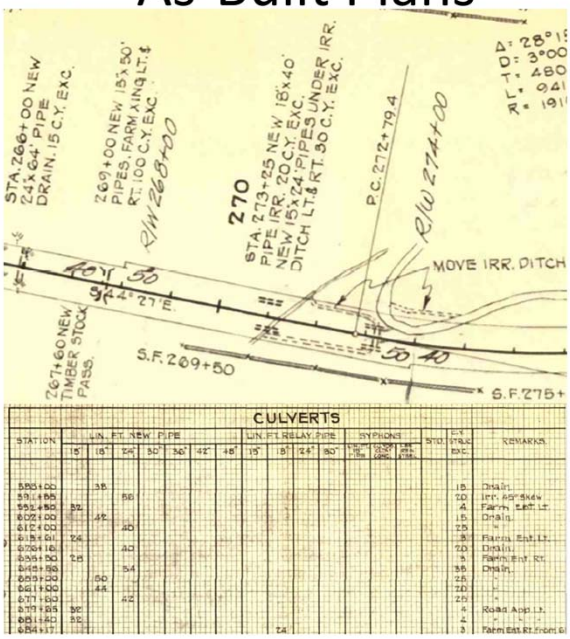
After we've created our horizontal and vertical alignments,

and the cross sections are generated,

it's time to start placing culverts.

The first culverts to be placed in the plans are the existing culverts.

As-Built Plans

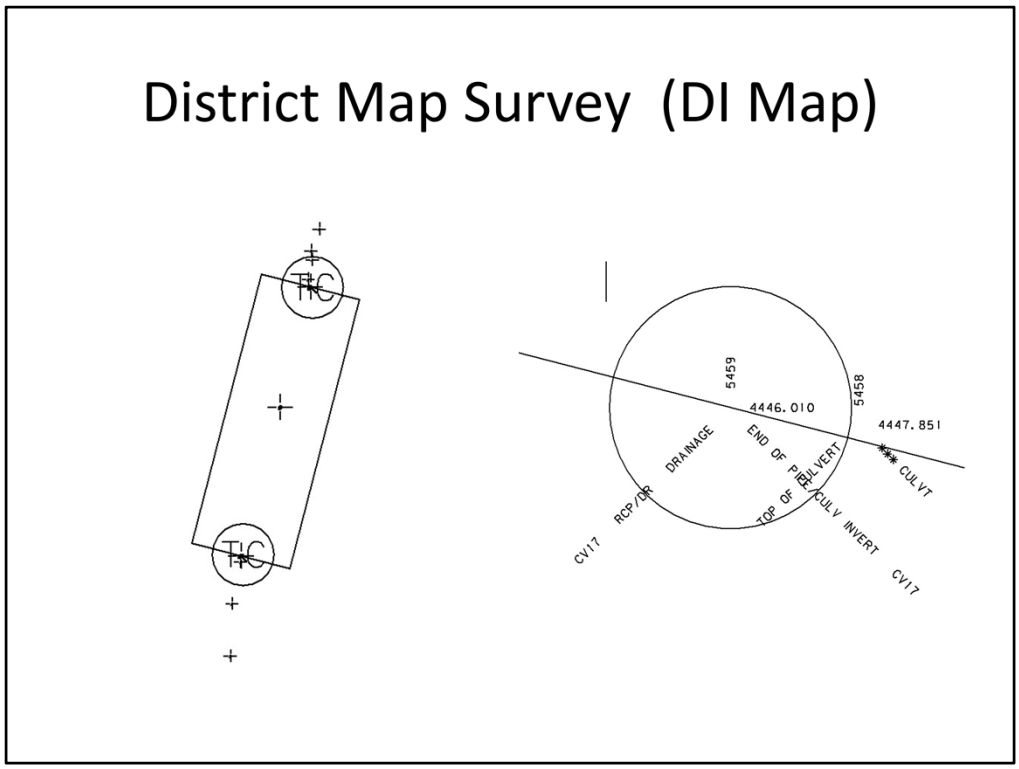


If you don't have a pickup survey available….

As – Built plans are a good source to look up existing culvert lengths.

The lengths are shown in the plan view as well as the culvert summary frames.

District Map Survey (DI Map)



A better source to find out the existing pipe material and lengths is in the DiMap.

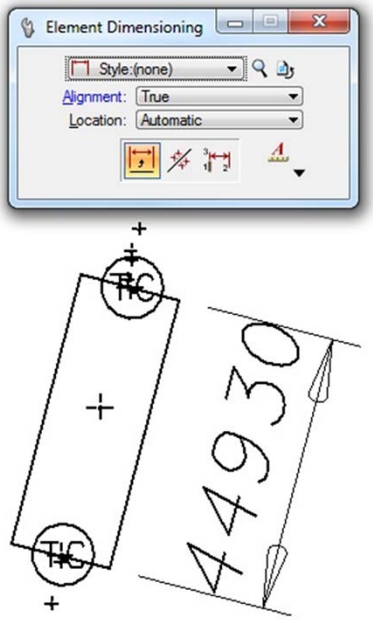
The location or pick-up surveys will locate the existing pipe culverts.

When you zoom into the end of the pipe, the pipe material is typically listed along with the top of culvert and invert elevations.

Subtract the elevations to get an estimate on the size of the pipe. This example is probably an 18” pipe.

These sizes and lengths should be checked against the As-Built plans. If they are different, further investigation is warranted.

Find Existing lengths

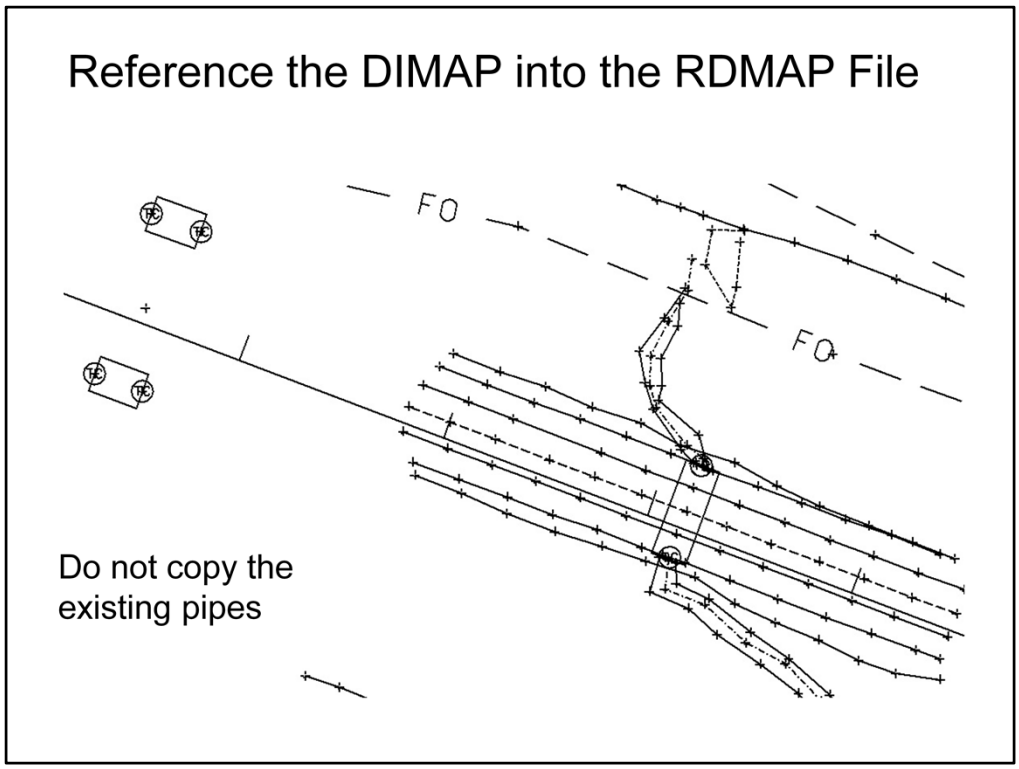


You can find the existing pipe lengths by using the MicroStation tool…. Element Dimensioning.

Select True

and measure existing pipe lengths in the DI Map.

This pipe is 44.9 ft.



Show existing pipes in the plan view by turning on the appropriate level in the Dimap.

Do not copy the elements in the Road map file.

They are already in the DIMap file and do not need to be added to the Road map file.

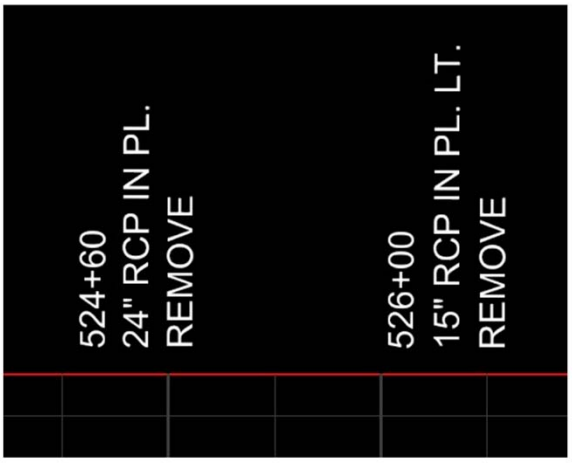
They will be referenced in. (A comment was made that the designer likes to copy the existing pipes into his RDMAP file so he can scale it down to true diameter size. The response is, as stated in the new Road Design Manual, Chapter 12, page 12-17, bullet 7;

“Culvert ends should accurately reflect their locations and direction of flow, though the culvert width may be exaggerated for clarity. Similarly, items such as manholes, telephone pedestals, signs, or other items represented by symbols should be located as accurately as possible but scaled such that the symbol can be clearly identified when the plans are printed.”)

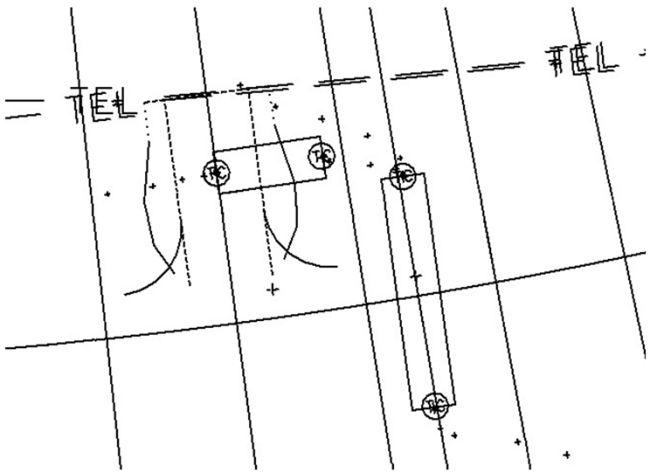
When showing Existing Pipes on the Plan Sheet

Place notes vertically at the bottom of the plan view

- Station
- Size of pipe
- Pipe material
- In PL. (in place)
- Left or Right for approaches
- Remove , Use As Is, Plug & Abandon or Fill & Abandon

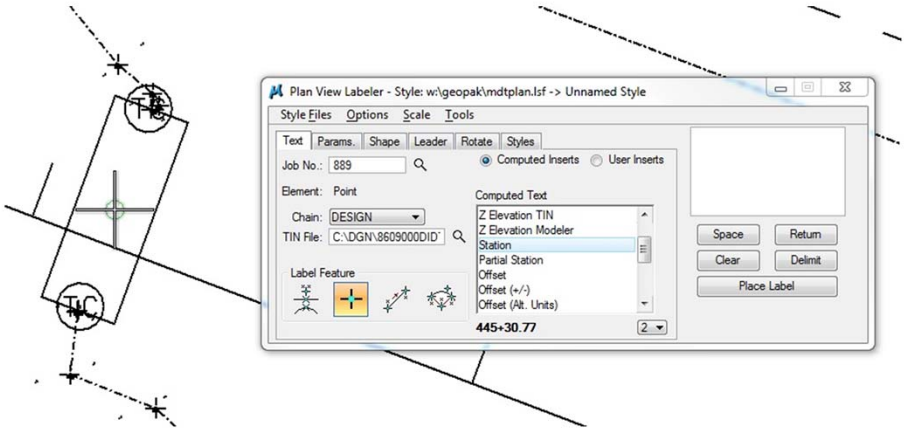


Place a pattern line at the centerline of existing pipe crossings when regular pattern lines are not close



After you place your pattern lines in your map file, you will need to go back and add additional pattern lines at the existing pipe locations.

From the DI Map, get stations and offsets by using the Plan View Labeler in Geopak.



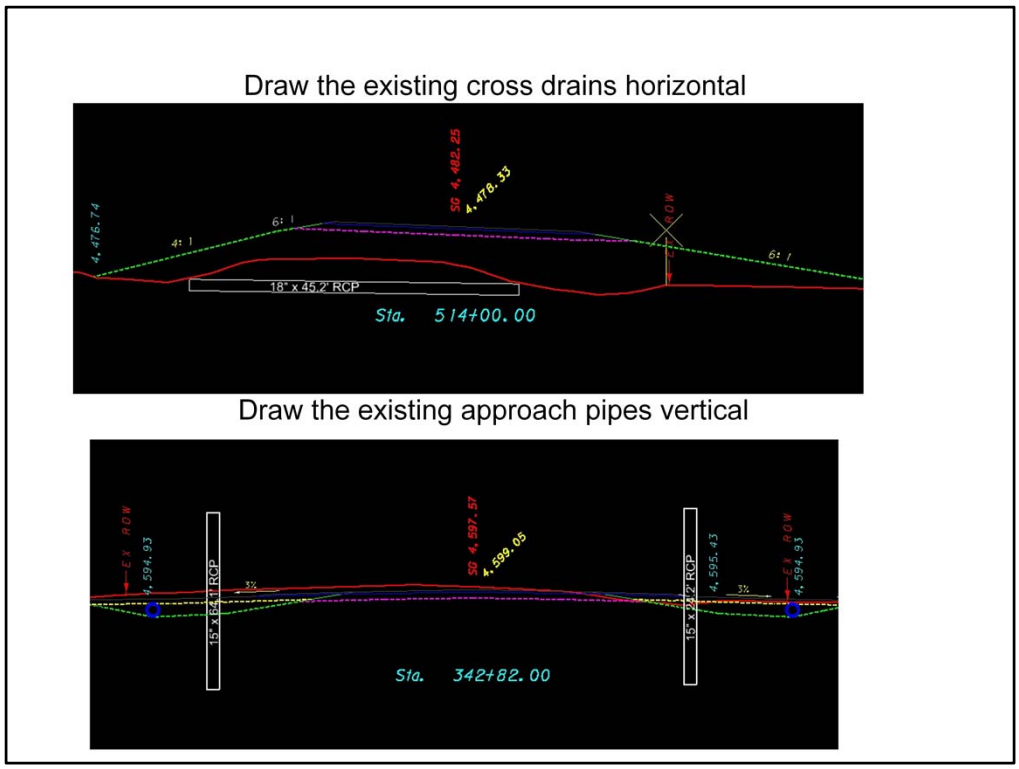
Since we really don't have an automatic way of placing existing pipes in our cross sections…

….use the Plan View Labeler to get accurate stations and offsets for existing pipes.

Click on the center of the pipe to get the centerline station of the existing pipe. (A question came up on locating the existing pipe. Should it be where the existing pipe crosses the new centerline or the center of the existing pipe. My question back would be, how would you locate the existing pipe if it were not touching the new centerline? The answer is, at the centerline of the existing pipe, in all cases)

Click on the ends to get the offsets.

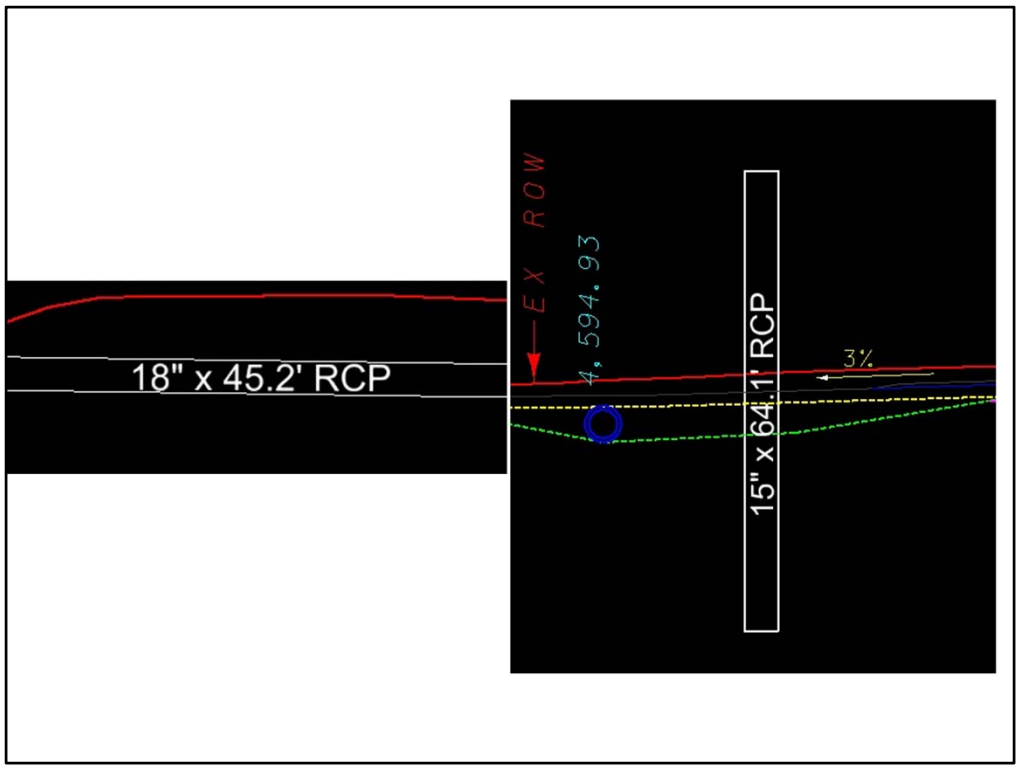
This will aid in placing the existing pipes accurately in your cross sections.



When placing existing pipes in the cross sections….

…draw the existing cross drains horizontal…

And existing approach pipes vertical



Label the size and length of the existing pipes inside the object lines

Place the notes on the right side in the Cross Section View

- Centerline Station
- Size
- Length of pipe
- Material
- In. Pl. (in place)
- Left or right for approaches
- Remove ,Use As Is, Plug & Abandon or Fill & Abandon

When labeling existing pipes in Cross Sections….

…..place notes on the right side of the cross section.

Existing pipes with station difference of 1’ or more need their own line
Rounding

STATION	CULVERT PIPE in	linear feet		linear feet	SKEW ANGLE	CULVERT IN PL. in x ft	
		LENGTH OF PIPE	REMOVE PIPE CULVERT	HEIGHT OF COVER			
387+91	108	108		4.6	12° LT		CONCRETE CUT PROTECTION AT
388+16			45.5			36 X 45.5 RCP	
406+69			49.1			18 X 49.1 RCP	
406+70	24	124		4.6	23° LT		DRAIN
418+00	24	64	61.0	1.2	15° LT	18 X 61.0 RCP	

- Existing pipes need their own line if their station is 1 foot or more different than the new pipe station.
- Round the **Station** to nearest foot
- Round the **Remove pipe culvert** length to the nearest tenth
- **Culvert in PL.** (in. x ft.) rounded to nearest tenth

When the existing pipe has it’s own line, it will match in all 3 locations through the plan set. (Plan sheets, cross sections and summaries)

Existing pipes that require extending will need to be shown as well.

New **Show existing culverts to be used in place**

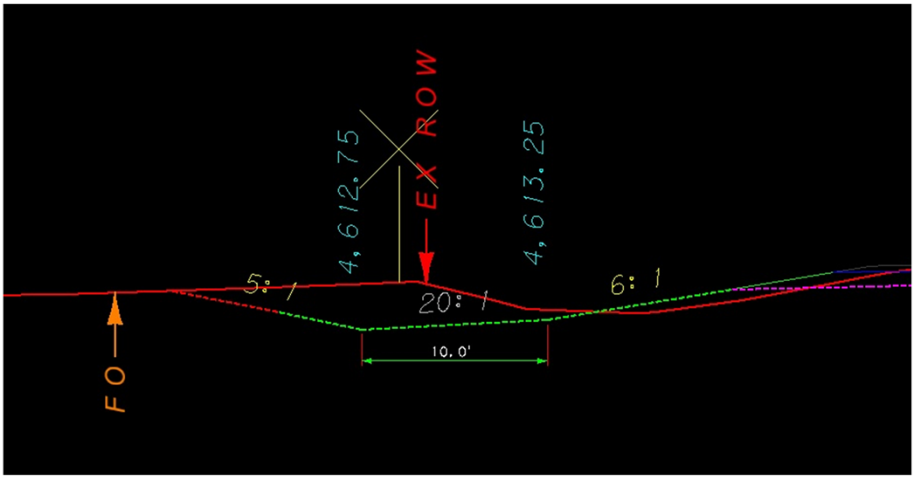
STATION	CULVERT PIPE in	linear feet		CULVERT IN PL. in x ft	REMARKS
		LENGTH OF PIPE	REMOVE PIPE CULVERT		
499+75	36	112			CONCRETE CUTOFF WALLS AND EDGE PROTECTION AT INLET AND OUTLET
500+80			39.8	36 X 45.5 RCP	
504+50				24 X 56.8 RCP	USE AS IS - DO NOT DISTURB
408+15	24	124			DRAIN
418+00			61.0	18 X 61.0 RCP	

- Existing pipes to be USE AS IS will now be listed in the Culvert Summary Frame
- When the existing pipe has it's own line, it will match in all 3 locations through the plan set. (Plan sheets, cross sections and summaries)

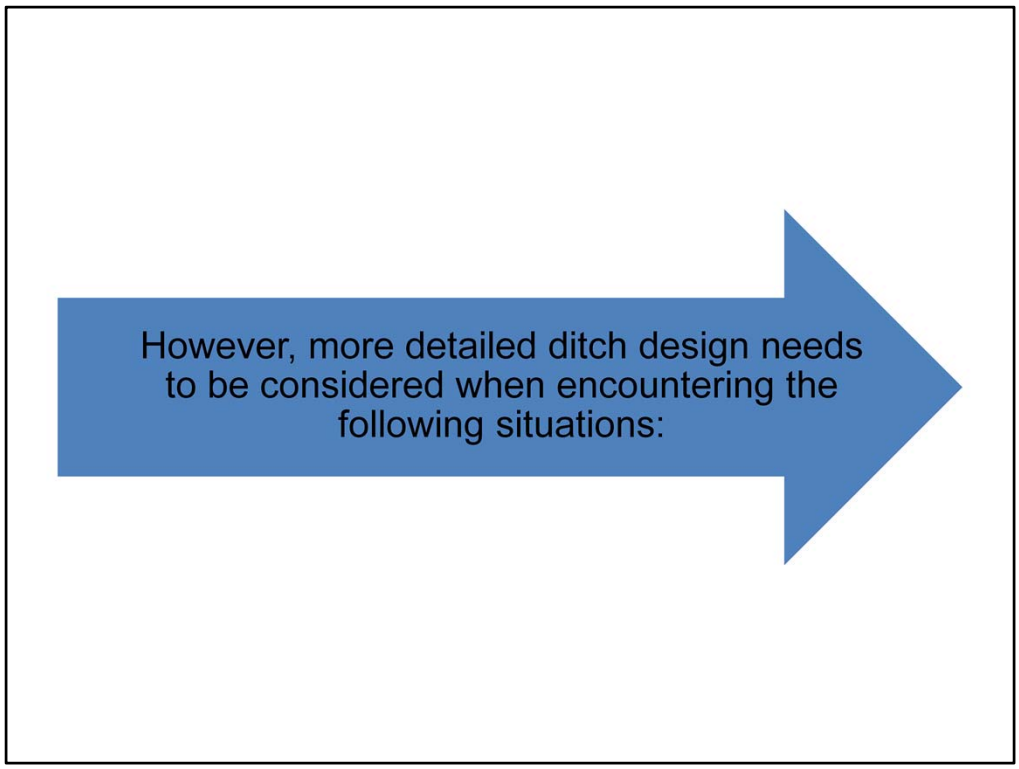
Roadside drainage

Typical Ditch

10’ Flat - bottom
Match profile grade of the roadway



Roadside ditches generally utilize a 10’ flat-bottom configuration and the grade of the roadside ditches typically matches the profile grade of the roadway.



However, more detailed ditch design needs to be considered when encountering the following situations:

Sustained grades

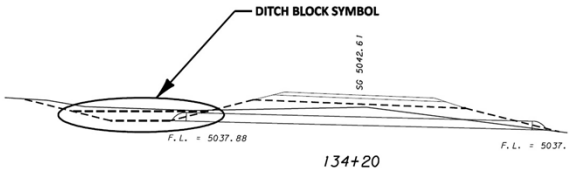
May carry high volumes of runoff…….
……which can result in erosion

Ditches on sustained grades may carry relatively high volumes of runoff, which can result in erosion to the ditch……

Sustained Grades

When sustained grades are encountered the designer needs to consider the use of erosion control protection:

- cross drains
- ditch blocks
- check structures
- lined ditches



Cut-to-fill transitions

Another situation is the Cut to fill transitions.

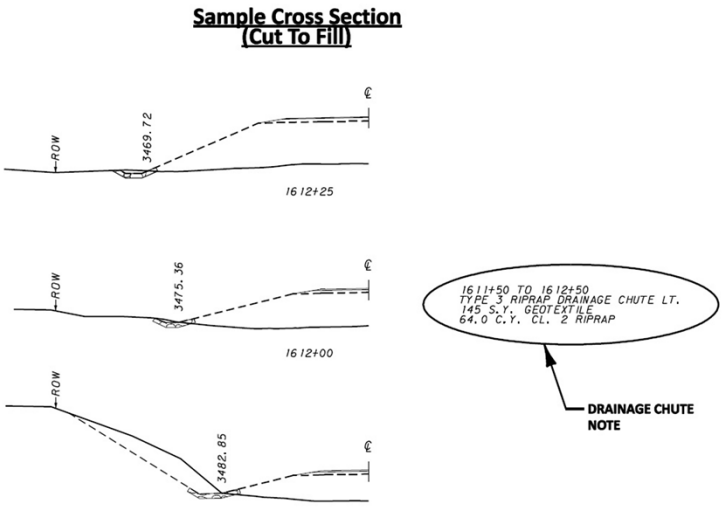
Cut-to-fill transitions may carry high volumes of runoff…..(next slide) which can result in erosion to the ditch……

Cut-to-fill transitions

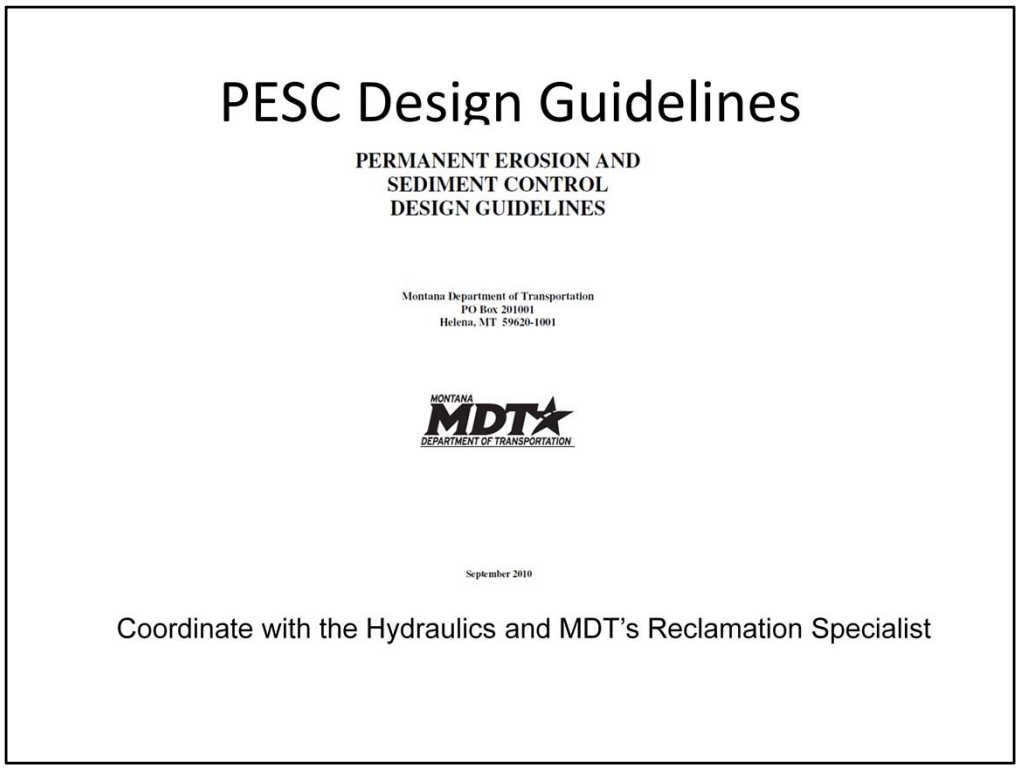
…..which can result in erosion to the ditch

Cut to Fill Transitions

- Use erosion protection such as riprap chutes and embankment protectors.



The designer should use erosion protection such as riprap chutes and embankment protectors to protect the ditch.



The designer should also coordinate with….

….. the Hydraulics Section

…..and MDT's Reclamation Specialist

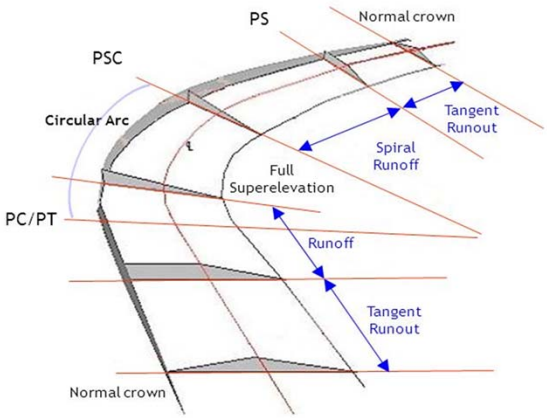
……and refer to the Permanent Erosion and Sediment Control (PESC) design guidelines for current erosion control methods.

Another situation is Flat Ditches.

Extremely flat ditches may not drain properly.

Separate ditch grades need to be considered for 50’ on each side of the crest if the grades along the curve are 0.30% or less.

Basics - review

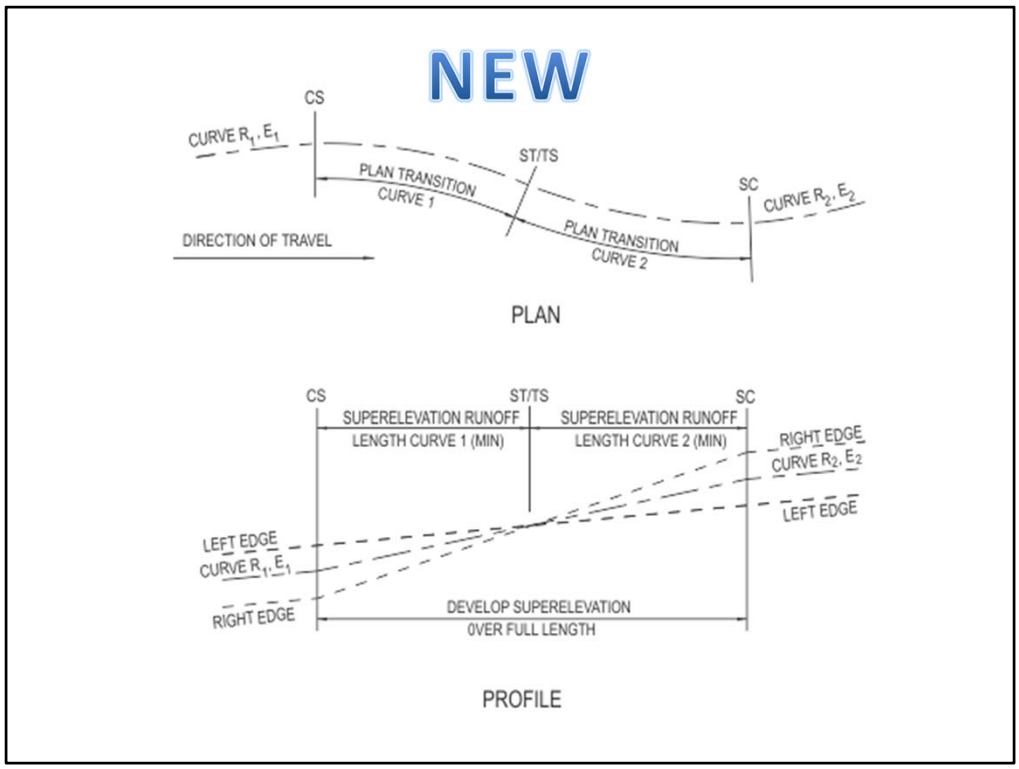


Spiral curve

Tangent to curve

Design a separate ditch grade on high side of superelevated if the profile grade is 0.50% or less

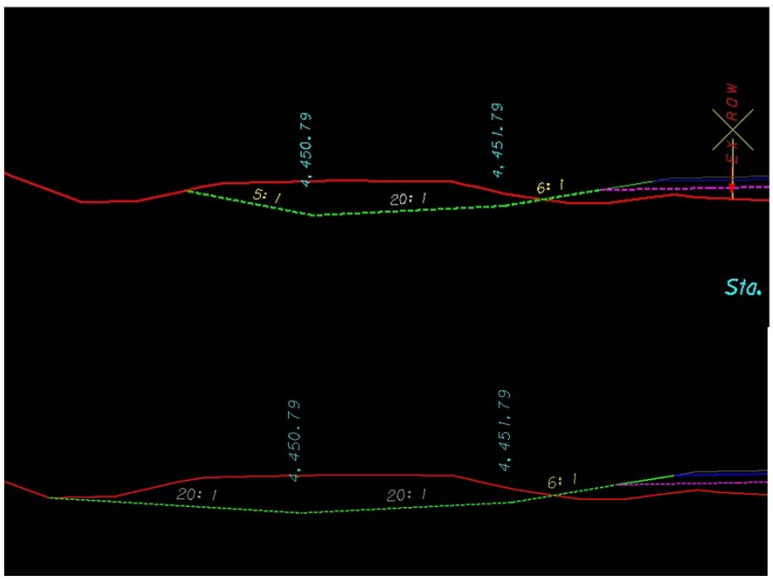
Separate ditch grades may also be necessary on the high side of a superelevated section where the profile grade is 0.5% or less. (next slide)



We are in the process of changing the way we do our superelevations. We have typically rotated about the low shoulder but soon we will designing to rotate about the centerline. This may cause ponding issues on the low side of the inside curve, especially on 8% superelevations and wide shoulders.

Rotation about the low shoulder will still be considered on a case by case basis.

Double Ditch

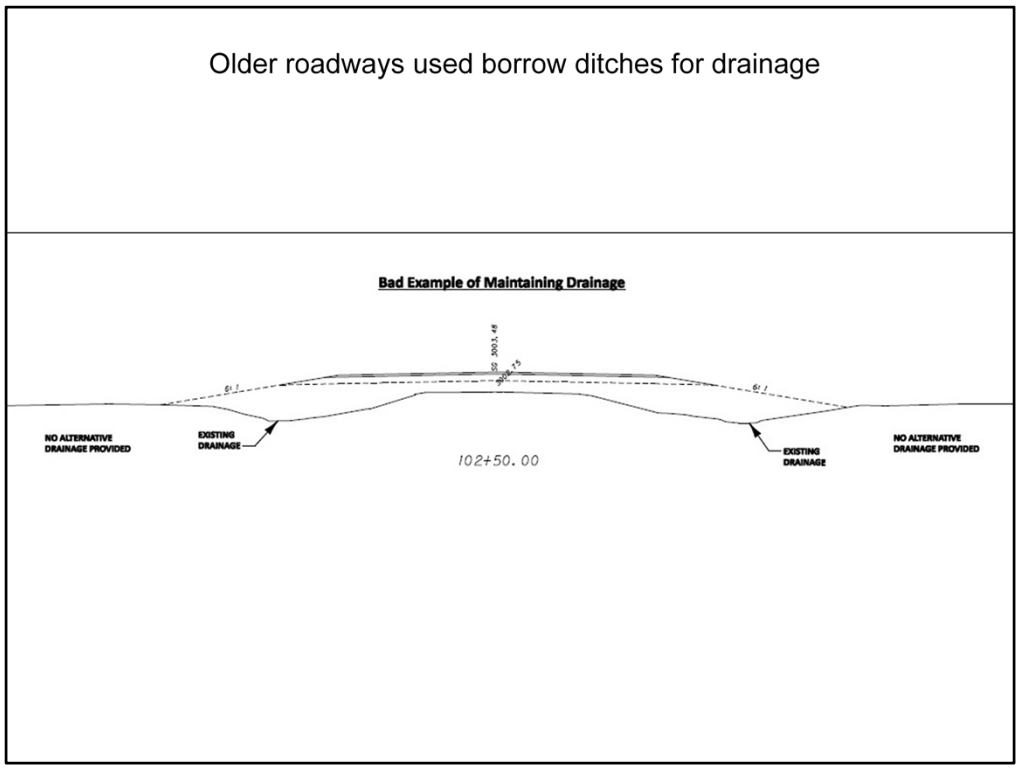


Another situation is the Double Ditch.

Double ditch situations should also be avoided.

By modifying the backslope……

….. a double ditch can be eliminated.



Many older sections of roadway were constructed using side borrow …

…..which resulted in substantial road-side ditches adjacent to the roadway embankment.

These borrow ditches would carry the runoff to natural drainage paths.

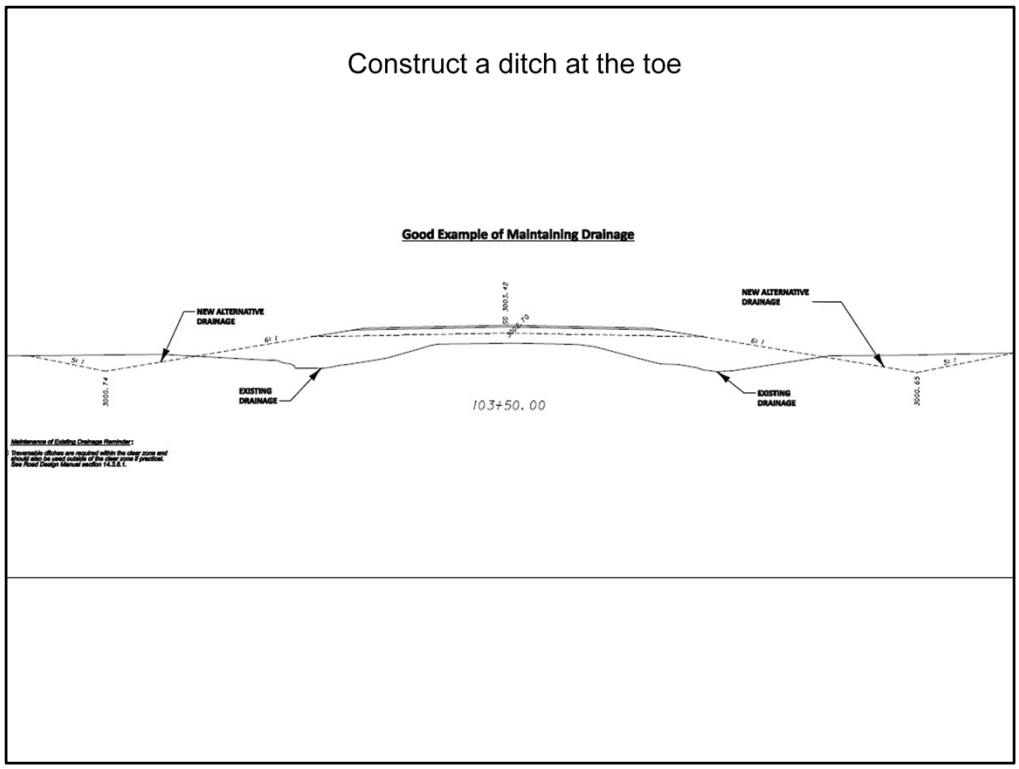
New wider templates often fill these ditches….

…..leaving no clear drainage path and often pushing runoff onto adjacent landowners.

Here’s an example of when a borrow ditch was eliminated.

The drainage now flows into the adjacent field.

Designers should review these areas to determine if additional cross drains will alleviate the problem.



Construct a drain ditch at the toe of fill …..

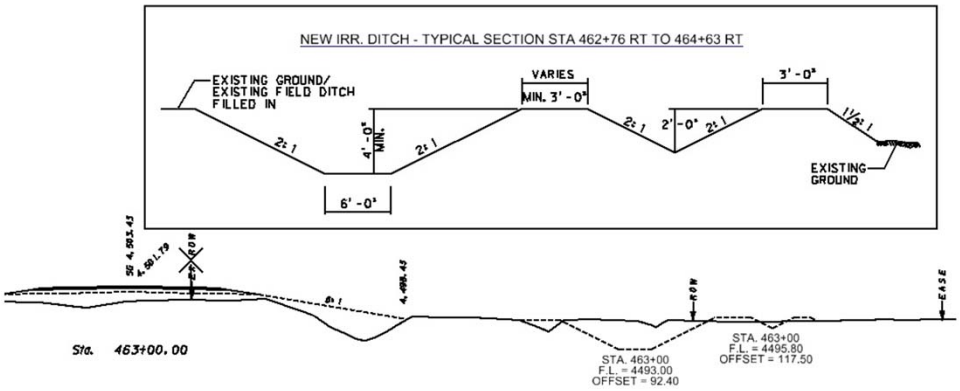
This may be needed to convey runoff to a natural drainage.

Talk with the Hydraulics section too.

If the roadside ditch is used for irrigation…

Make sure the ditch is out of the clear zone

Preferably out our out R/W but not always possible - easement



Sometimes providing a ditch typical in cross section is helpful

……the designer should coordinate with the Hydraulics Section

Drainage in the roadside ditch is sometimes complicated by landowners who use the roadside ditch to carry irrigation wastewater.

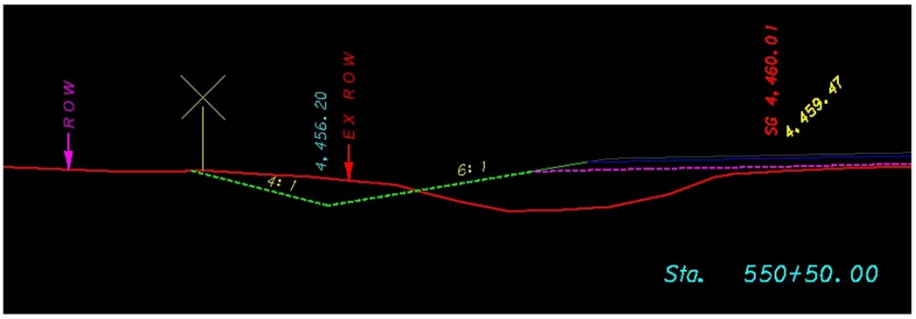
Although we prefer to have irrigation wastewater ditches, like all irrigation facilities, constructed outside of the highway right-of-way, perpetuation of irrigation wastewater in the roadside ditch should be evaluated on a case-by-case basis.

Whenever the roadside ditch is used for any irrigation purpose the designer should coordinate with the Hydraulics Section.

Modify ditches for positive drainage…..

….by flattening the ditch

or by steepening with v-ditches (traversable)



This may warrant a design exception

In some cases, modify ditches for positive drainage by flattening or steepening with v-ditches.

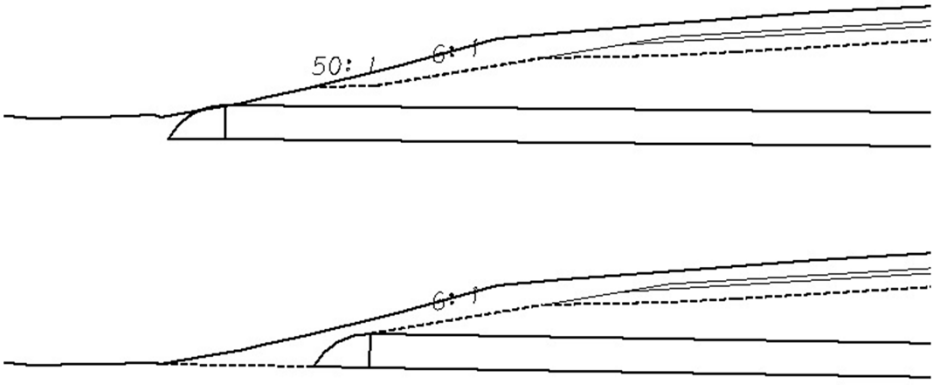
Make sure to provide a traversable V-ditch.

See the Roadside Design Guide or the Road Design Manual for guidance.

Stay within design standards and make sure to avoid abrupt changes.

Modify ditches to shorten pipes

Geopak generated

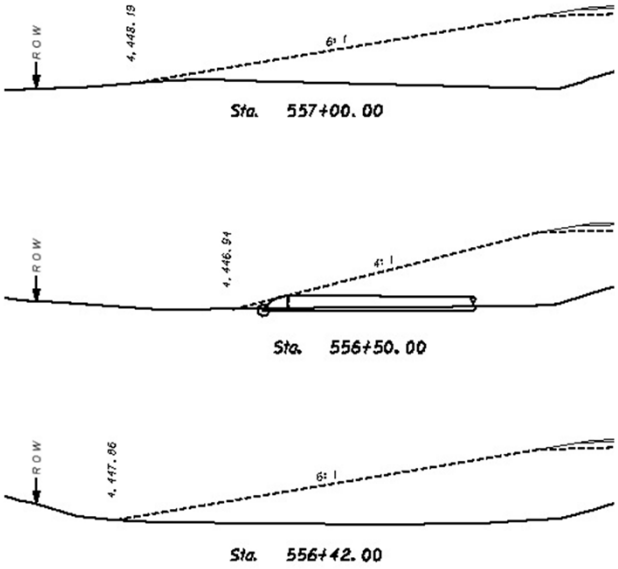


Extend 6:1 down and shorten the pipe length

Modify Geopak generated ditches to shorten pipes if possible.

Adjacent cross sections

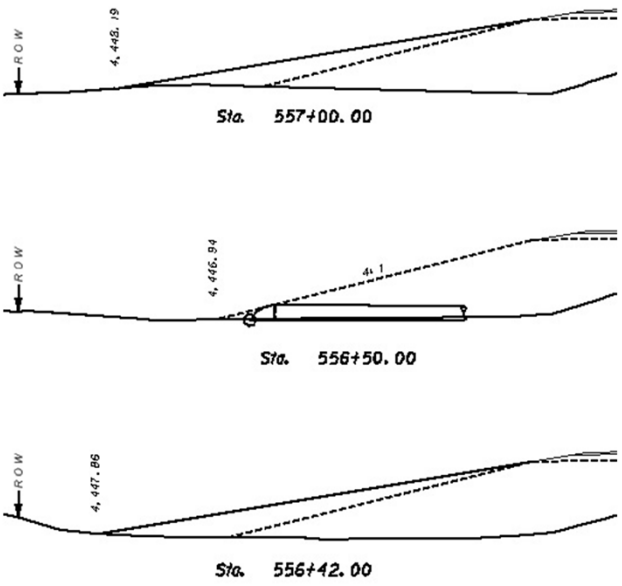
Steepen the adjacent cross sections to 4:1 for a smoother transition



If the cross section at the pipe is a 4:1 but the cross sections before and after are flatter, steepen the adjacent cross sections to 4:1 for a smoother transition.

Adjacent cross sections

- Will shorten the pipe length
- Reduce Environmental Impacts
- A design exception may be warranted



A design exception will be necessary in this case.

New Culverts

So now that we covered ditch drainage, let's talk about new culvert placements.

Mainline drainage Culverts

At least 24” in diameter

All new mainline drainage culverts must be at least 24” in diameter.

Approach and Irrigation Culverts

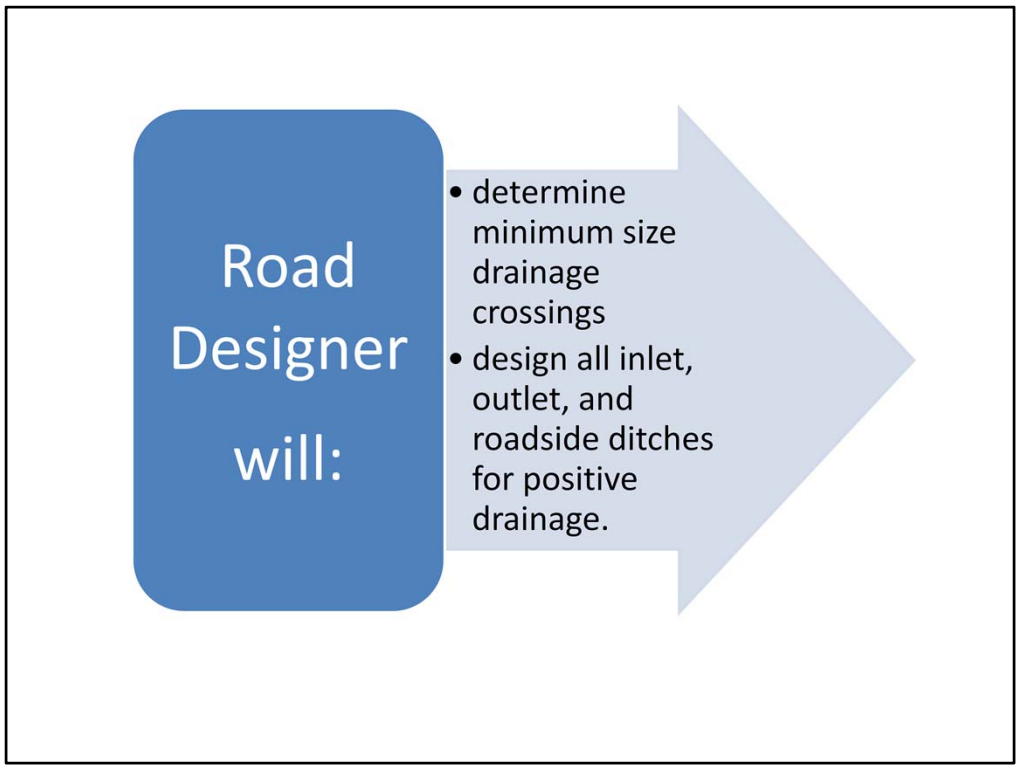
At least 18” in diameter

or an equivalent arch pipes

All new irrigation pipe culverts and approach culverts must be at least 18” in diameter. Equivalent arch pipes may be used.

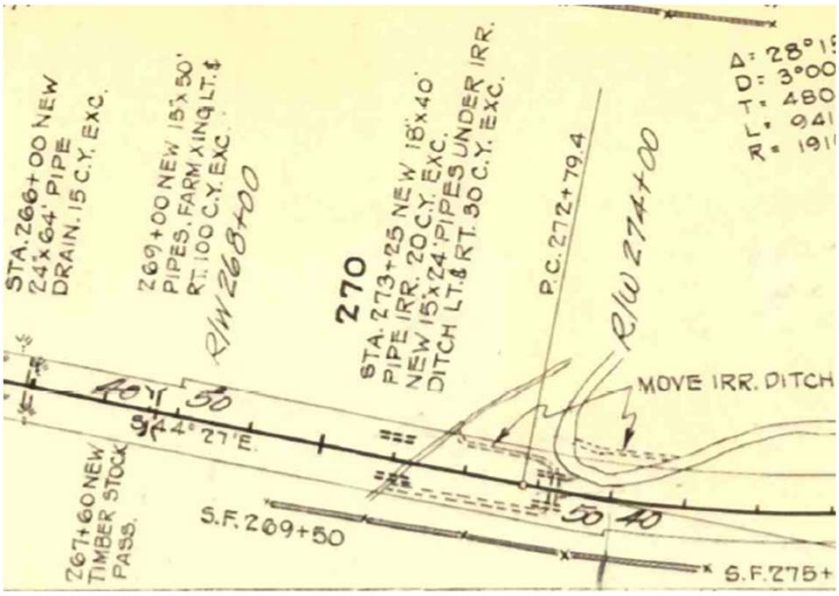
Hydraulics is responsible for pipes >24” in diameter

The Hydraulics Section will provide recommendations for all irrigation and drainage crossings requiring culverts greater than 24” in diameter.



The road designer will determine the location of all minimum size drainage crossings and will design all inlet, outlet, and roadside ditches for positive drainage.

Review As-Built Plans



When deciding where to put new culverts….

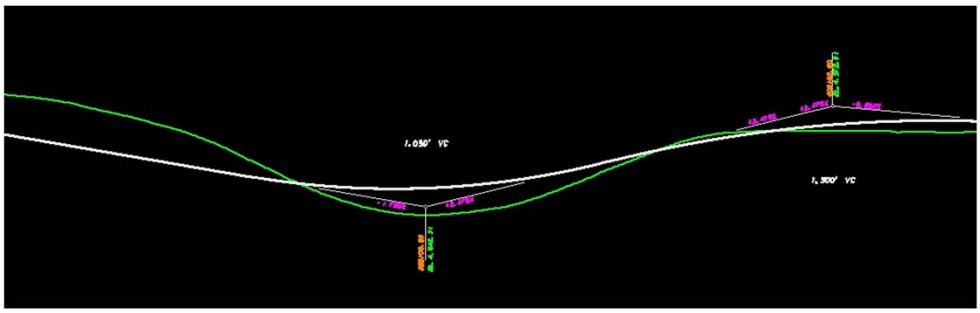
…. review as-built plans to determine the location of existing culverts.

Field Reviews

Also, during on-site reviews (PFR & AGR) ….

…..determine the location of minor natural drainages and areas that appear to be ponding.

New profile grade



Review the new profile grade to ensure that cross drains are provided in low spots

When a project involves modification to the existing vertical alignment…..

….. the designer must also review the new profile grade to ensure that cross drains are provided in low spots….

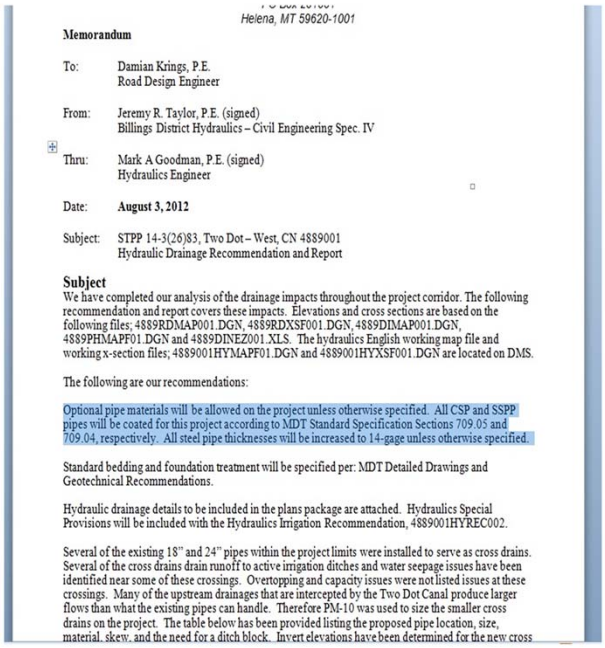
….. where water would otherwise be trapped.

…..Also, mention any vertical profile adjustments to the Hydraulics Engineer to make sure any new pipes will fit within the new profile.

The key is to communicate with Hydraulics.

Hydraulics Drainage or Irrigation Recommendation and Report

- Optional culvert materials
- coatings
- Proposed culvert sizes and locations
- Skews
- Culvert wall thickness
- Size of corrugations
- Class of RCP
- Invert elevations
- End treatments



Helena, MT 59620-1001

Memorandum

To: Damian Krings, P.E.
Road Design Engineer

From: Jeremy R. Taylor, P.E. (signed)
Billings District Hydraulics – Civil Engineering Spec. IV

Thru: Mark A Goodman, P.E. (signed)
Hydraulics Engineer

Date: **August 3, 2012**

Subject: STPP 14-3(26)83, Two Dot – West, CN 4889001
Hydraulic Drainage Recommendation and Report

Subject

We have completed our analysis of the drainage impacts throughout the project corridor. The following recommendation and report covers these impacts. Elevations and cross sections are based on the following files; 4889RDMAP001.DGN, 4889RDXSF001.DGN, 4889DIMAP001.DGN, 4889PHMAPF01.DGN and 4889DINEZ001.XLS. The hydraulics English working map file and working x-section files; 4889001HYMAPF01.DGN and 4889001HYXSF001.DGN are located on DMS.

The following are our recommendations:

Optional pipe materials will be allowed on the project unless otherwise specified. All CSP and SSPP pipes will be coated for this project according to MDT Standard Specification Sections 709.05 and 709.04, respectively. All steel pipe thicknesses will be increased to 14-gage unless otherwise specified.

Standard bedding and foundation treatment will be specified per: MDT Detailed Drawings and Geotechnical Recommendations.

Hydraulic drainage details to be included in the plans package are attached. Hydraulics Special Provisions will be included with the Hydraulics Irrigation Recommendation, 4889001HYREC002.

Several of the existing 18" and 24" pipes within the project limits were installed to serve as cross drains. Several of the cross drains drain runoff to active irrigation ditches and water seepage issues have been identified near some of these crossings. Overtopping and capacity issues were not listed issues at these crossings. Many of the upstream drainages that are intercepted by the Two Dot Canal produce larger flows than what the existing pipes can handle. Therefore PM-10 was used to size the smaller cross drains on the project. The table below has been provided listing the proposed pipe location, size, material, skew, and the need for a ditch block. Invert elevations have been determined for the new cross

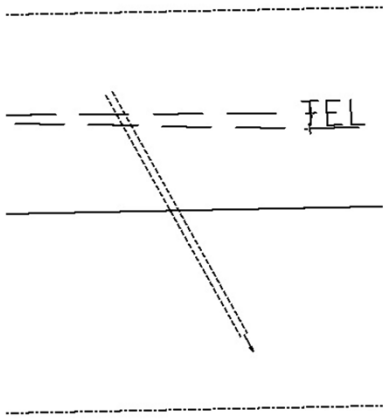
Refer to the Hydraulics Drainage or Irrigation Recommendations and Reports for:

Map File

Show new pipes at the station and skew recommended in the report.

Show the pipes using dashed lines or the custom line style P_Drainage_Culvert.

Show the cross drains and approaches with the flow direction.



First of all, we get our recommendations from the Hydraulics Engineer report. Place the pipes in the map file at the station and skew recommended in the report.

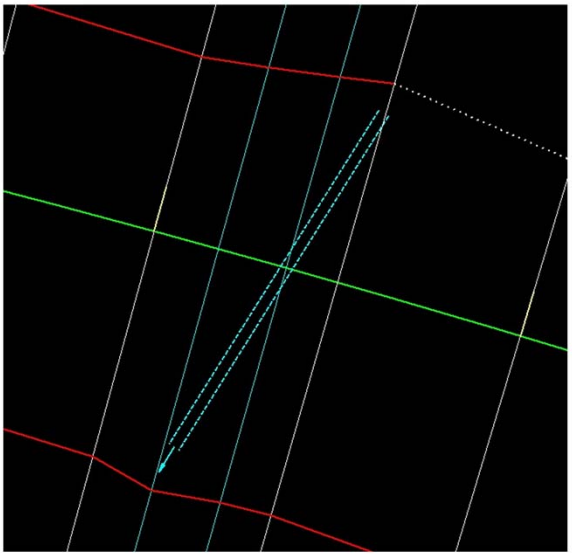
As stated in the new Road Design Manual, Chapter 12, page 12-17, bullet 7;

“Culvert ends should accurately reflect their locations and direction of flow, though the culvert width may be exaggerated for clarity. Similarly, items such as manholes, telephone pedestals, signs, or other items represented by symbols should be located as accurately as possible but scaled such that the symbol can be clearly identified when the plans are printed.”

Map File

Place pattern lines at the center of the culvert.

If the skews are greater than 5°, place pattern lines near ends to show on cross sections.



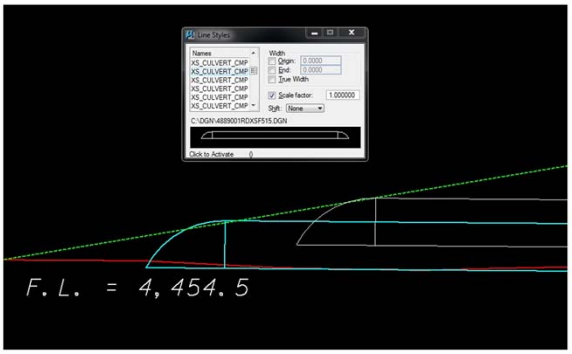
Place pattern lines at the center of the culvert. If the skews are greater than 5°, place pattern lines near ends to show on cross sections.

Cross Section

Layout the pipe by fitting the square end of the pipe to catch the foreslopes.

Set at invert elevations if provided by Hydraulics. (F.L. = 4,454.5)

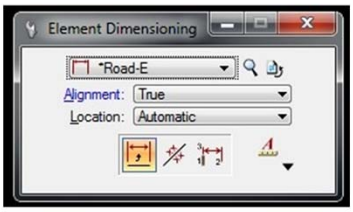
If not specified by Hydraulics, place invert elevations where pipe will drain.



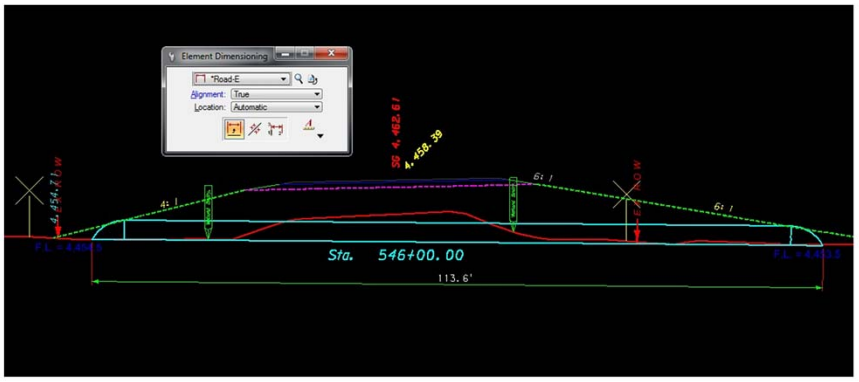
After placing pattern lines at the culvert locations, generate the new cross sections. Use custom line styles when drawing culverts in the cross sections

Length of a Culvert with a skew of 5° degrees or less

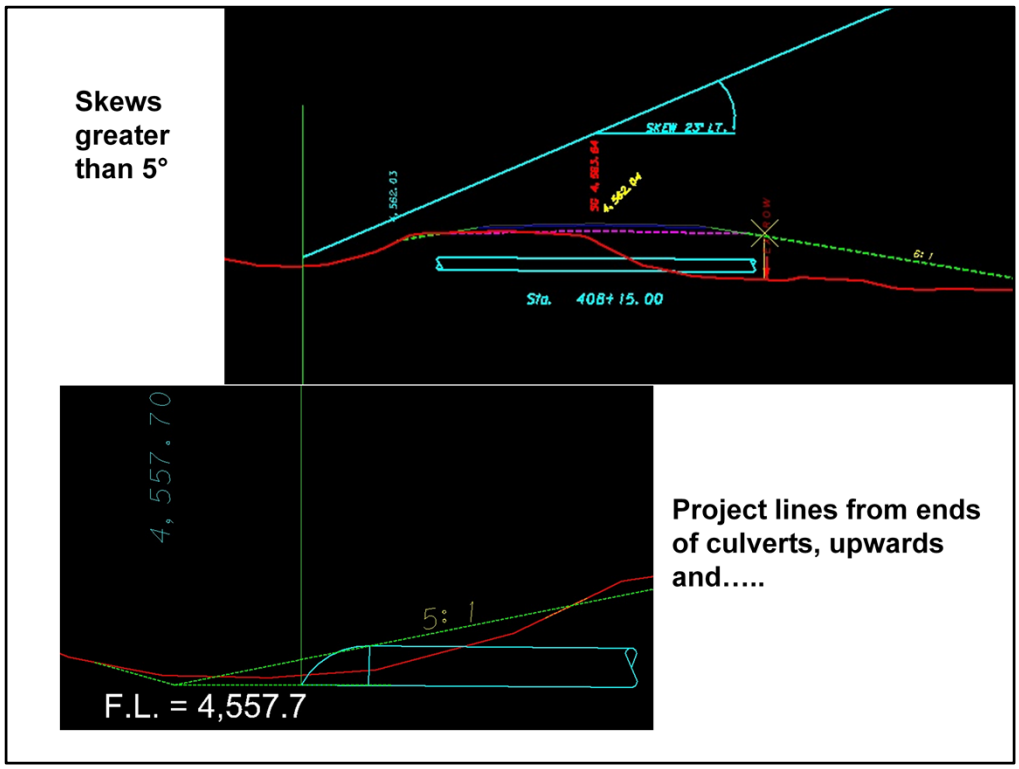
Use the Element Dimensioning tool.



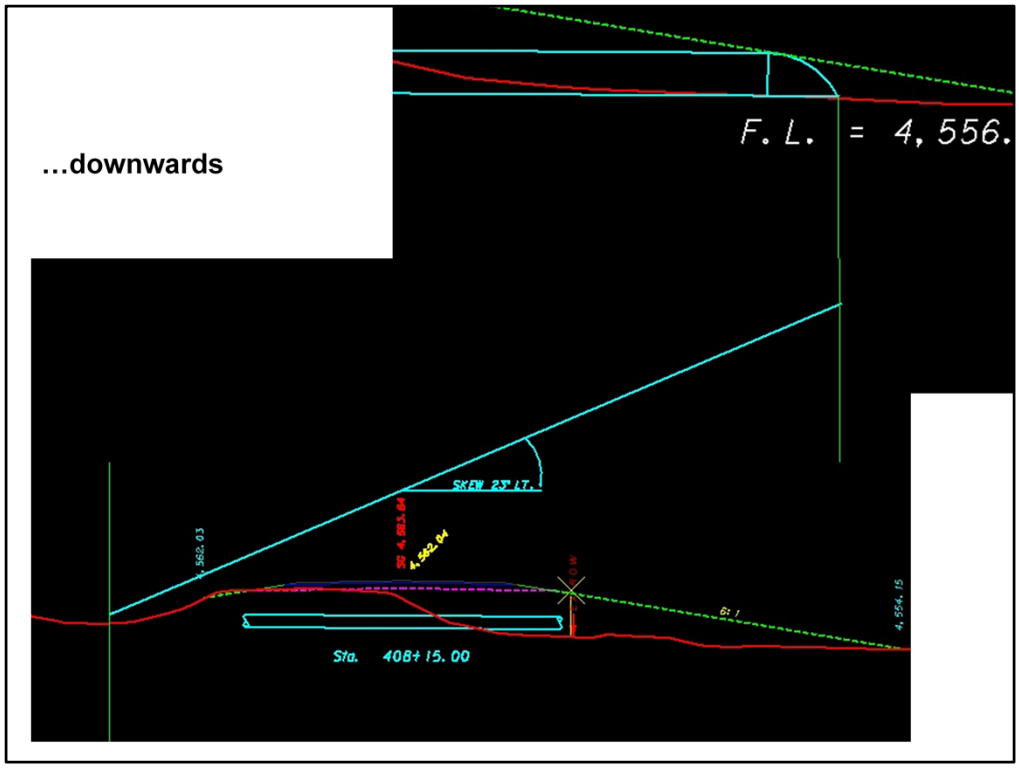
Alignment: True



Select the Dimension Element tool, first icon, and place the dimension. Round the length up to the nearest 2 foot increment.

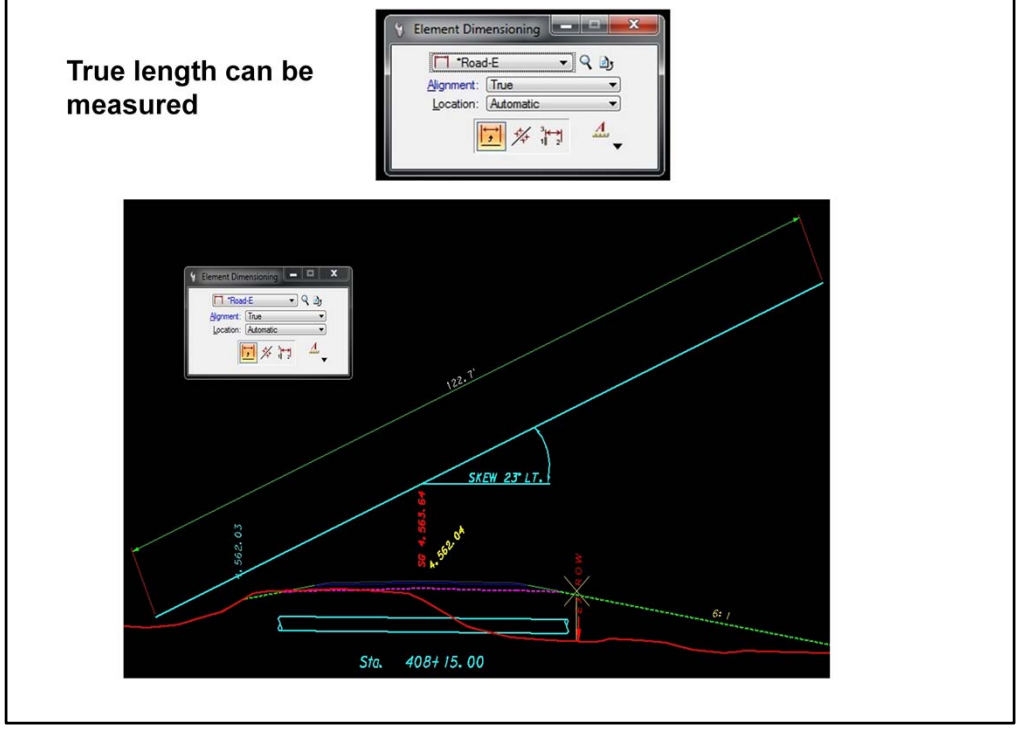


For culverts on a skew greater than 5 degrees, project lines from ends of culverts, upwards and…..



…and downwards. Extend the line in the plan view to touch the projected lines. Since large skews may require the use of two cross sections, one for the inlet and one for the outlet, you may need to go back to the map file and reposition the ends of the culvert in the plan view.

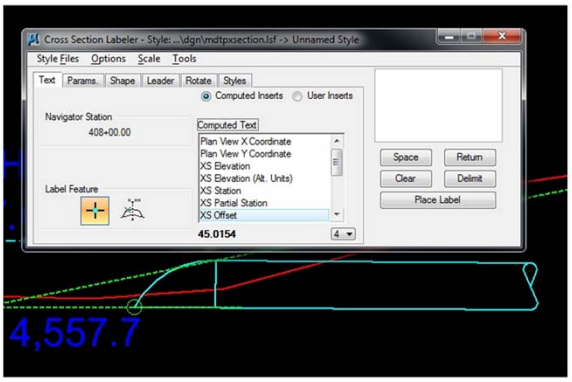
True length can be measured



After extending the lines, the culvert length can be scaled from the skewed line. It is important that the line is drawn at the correct skew angle. Round up to the next 2' increment.

Cross Section Labeler

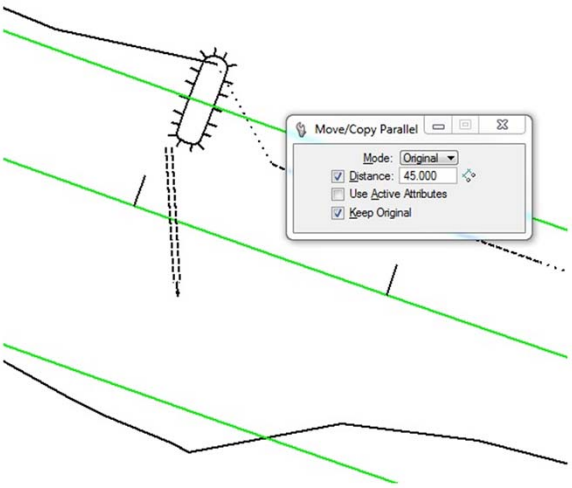
Use the Cross Section labeler to find out the offsets of the pipe and layout pipe in map file with appropriate skew and length.



Once the ends of the skewed culvert have been determined, use the Cross Section labeler to find out the offsets of the culvert and modify the ends in the map file to the correct length.

Extending the pipe in the plan view

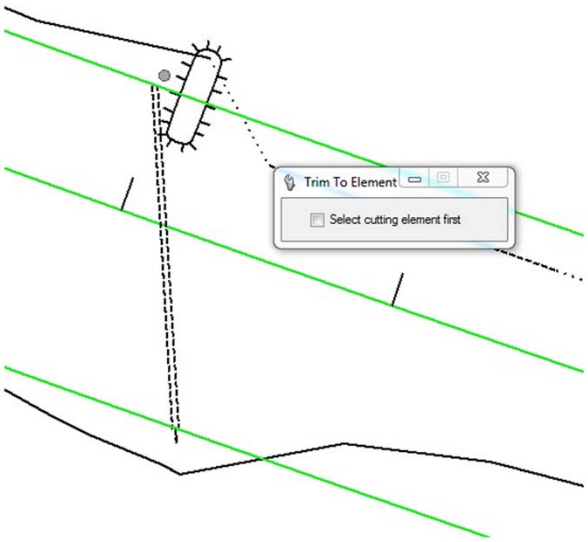
Copy parallel the alignment line the offset distances found in the cross sections



You can copy parallel the alignment element the offset distances found in the cross section labeler. Extend the lines to the new offsets. Then find the end stations of the new pipe using Plan View Labeler.

Extending the pipe in the plan view

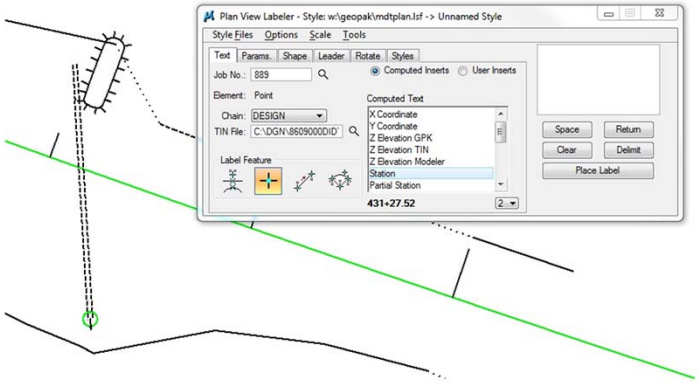
Extend the pipe to the new copied lines



Extend the lines to the new offsets.

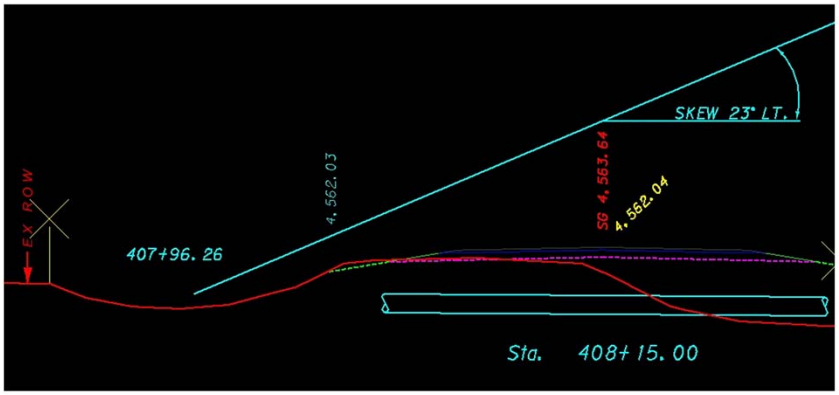
Extending the pipe in the plan view

Use the plan view labeler to determine the end stations of the new pipe.



Then find the end stations of the new pipe using Plan View Labeler.

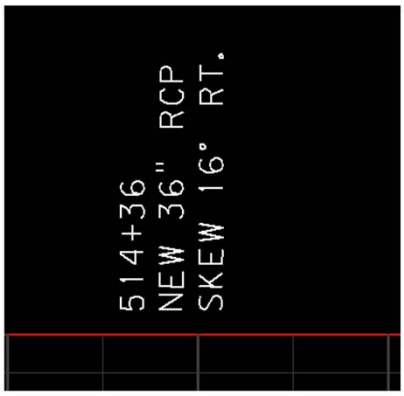
Label End Stations in the Cross Sections



Label the end stations at the culvert ends in the plan diagram of the culvert in the cross sections generated from the Plan View labeler.

Place culvert notes vertically at the bottom of the plan view.

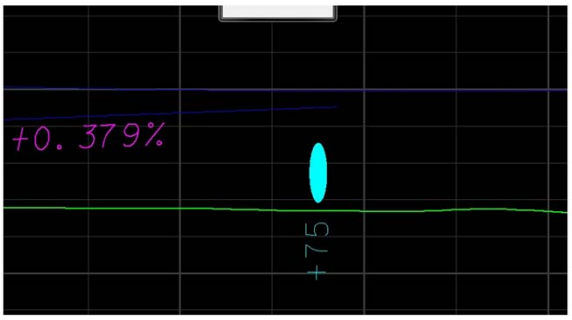
- Station to the nearest foot
- New pipe diameter
- Note the material type or Drain if it has Options
- Skew angle to the nearest degree (Left or Right)



Once you have the culvert stations, sizes and lengths figured out, you can now place that information in the plans. In the Plan/profile sheets, show the station to the nearest foot, new pipe diameter, the material type or Drain, left or right for approaches, skew angle to the nearest degree.

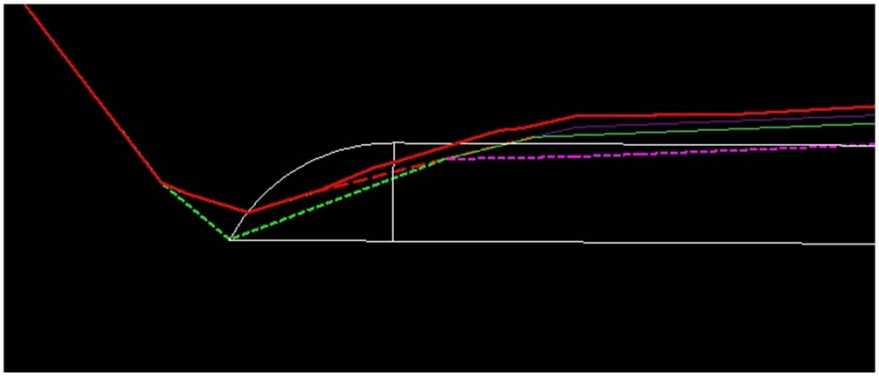
Profile View

Solid ovals with plus station



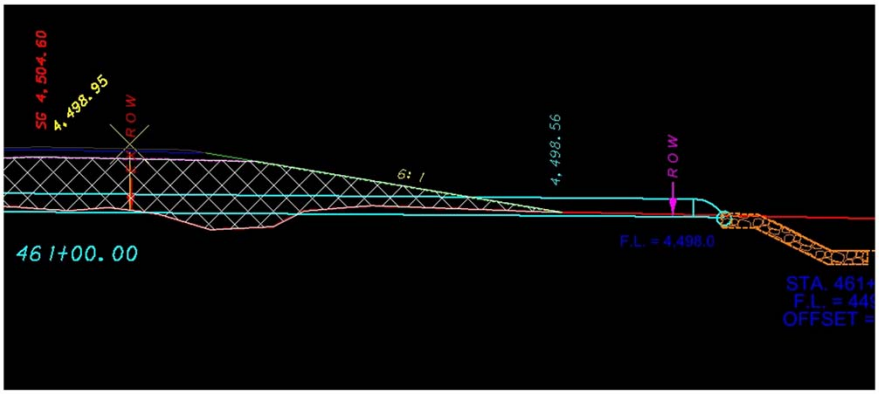
In profile view, show cross drainage pipes and structures as solid ovals and provide a plus station callout (e.g. for a pipe located at 20+75 show +75 at the pipe symbol in the profile view).

Avoid extending culverts in Surfacing Section



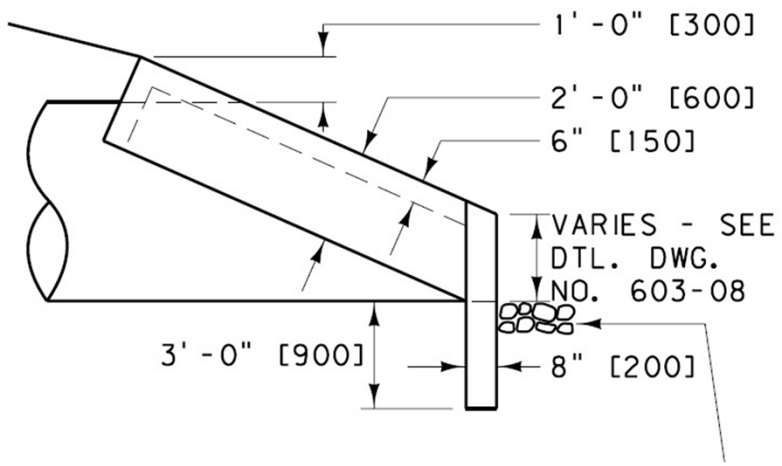
Pipes should not extend into the surfacing section.

OK in Special Borrow
…..but not desirable

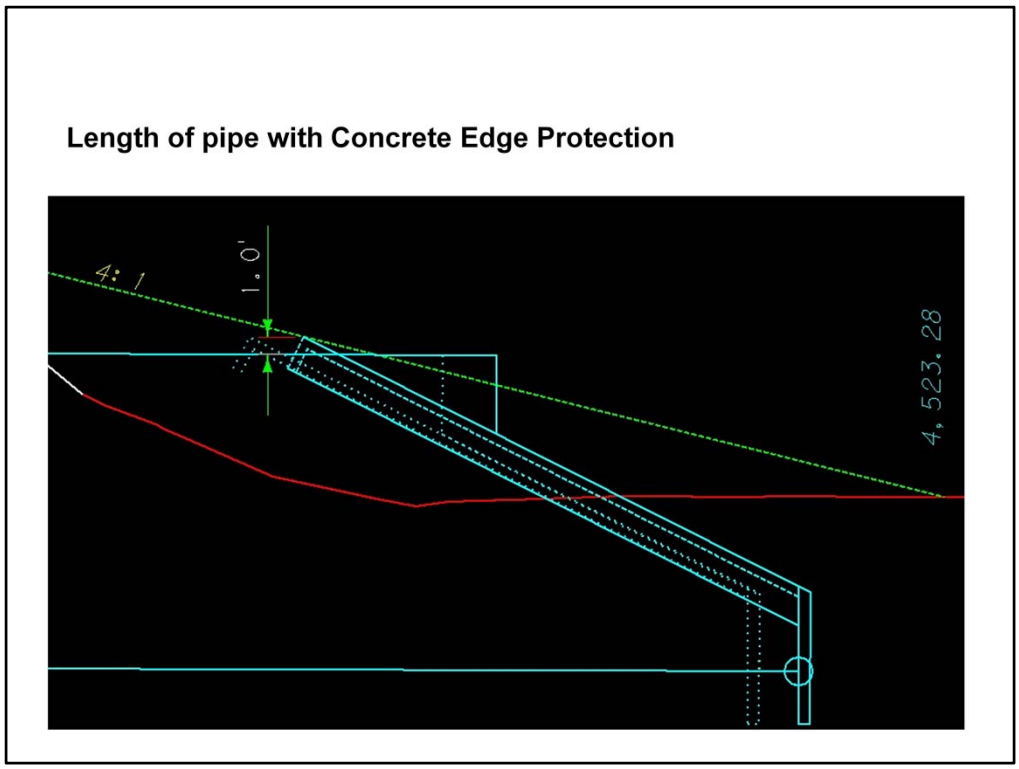


Although not desirable, pipes may extend into the special borrow course.

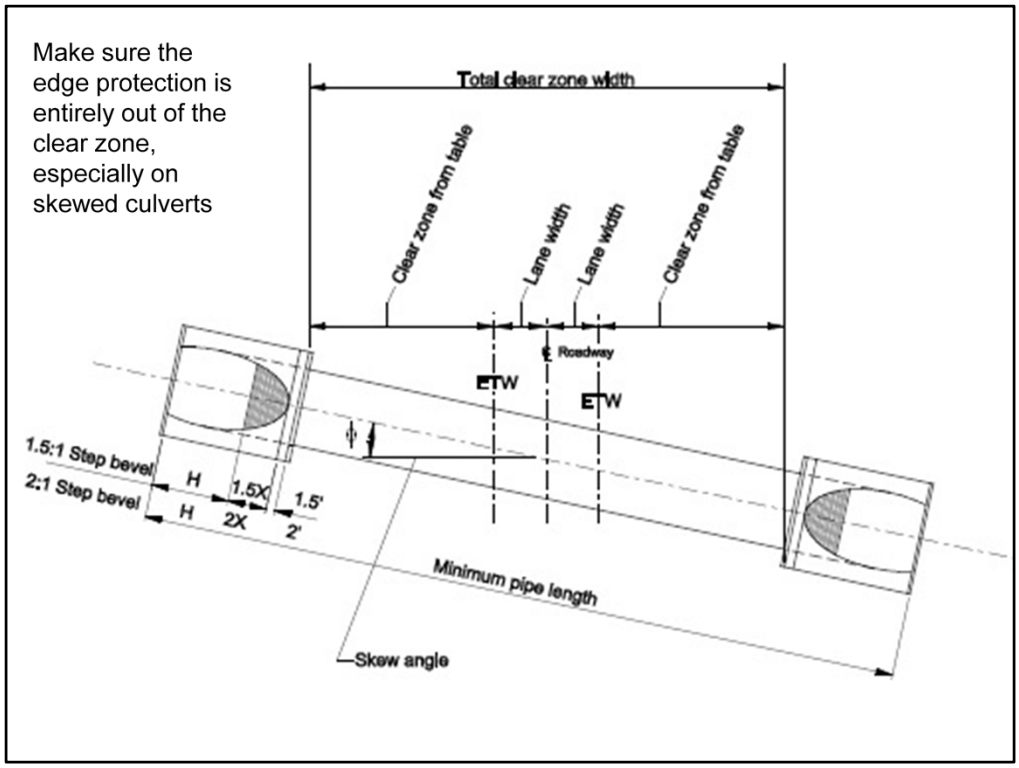
Length of pipe with Concrete Edge Protection



When a larger pipe requires concrete edge protection, refer to the detailed drawings for the placement diagrams. Extend pipe enough so that with edge protection 1’ above pipe, it catches the fill slope.



Here’s an example illustrating that.



Make sure the edge protection is entirely out of the clear zone, especially on skewed culverts.

Example 9-5: Minimum Length of Culvert

Background: The length of large culverts with concrete edge protection must be long enough so that the top portion of concrete edge protection is out of the clear zone. This is typically straightforward on culverts that are perpendicular to the roadway. However, when drawing culverts on a skew, make sure that the skewed corners of the concrete edge protection are out of the clear zone.

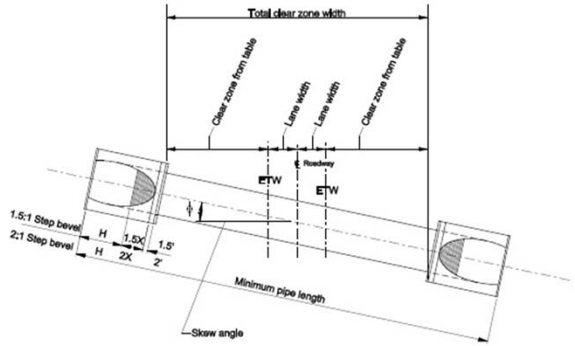
Use the following formulas to calculate the minimum lengths of skewed culverts to ensure that the concrete edge protection is out of the clear zone:

1.5:1 Step Bevel Formula:

$$\frac{(\sin\phi\,(0.5D + 4') \times 2 + \text{Total Clear Zone Width})}{\cos\phi} + (1.5' + 1.5X + H) \times 2 = \text{min. pipe length}$$

2:1 Step Bevel Formula:

$$\frac{(\sin\phi\,(0.5D + 4') \times 2 + \text{Total Clear Zone Width})}{\cos\phi} + (2' + 2X + H) \times 2 = \text{min. pipe length}$$



The new Road Design Manual has the calculation for **minimum culvert length** in Appendix K.

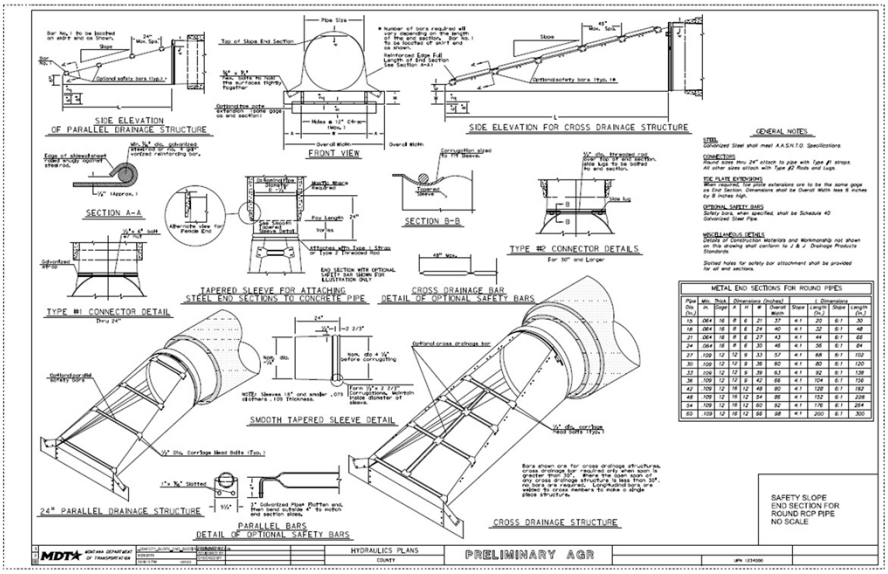
Openings larger than 36” are a hazard. Openings in the clear zone need to be protected.

End treatments make them traversable

If you can not locate the end of the culvert outside of the clear zone, end treatments wider than 36” can be made traversable. A special guard will need to be installed.

Bar grates or pipes can be used to reduce the clear opening width.

New Hydraulic Details for Safety Slope End Sections ≤ 60” Dia.

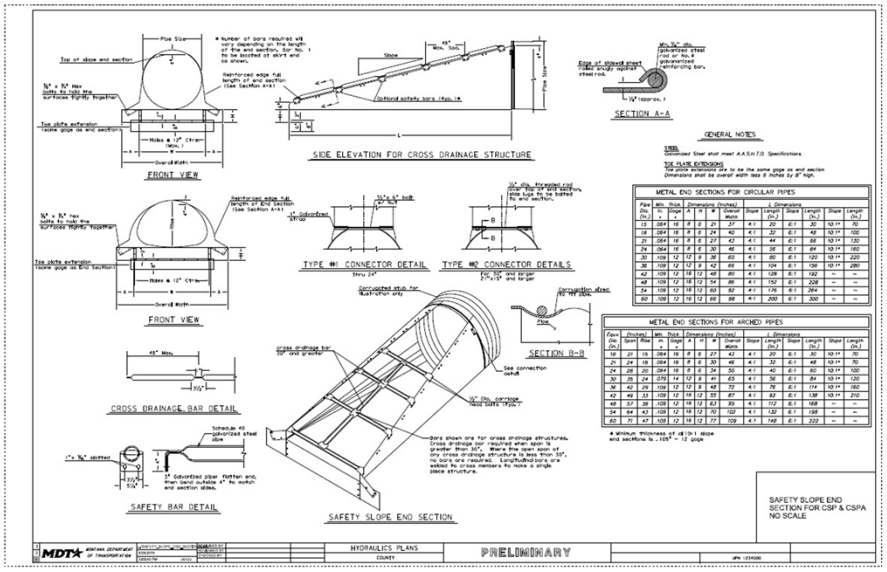


….for round RCP Pipe as well as…..

Bar grates or pipes can be used to reduce the clear opening width.

Openings larger than 36” are a hazard. Openings in the clear zone need to be protected.

…. as well as CSP & CSPA



Bar grates or pipes can be used to reduce the clear opening width.

Openings larger than 36” are a hazard. Openings in the clear zone need to be protected.

TOPICS - Part Two

- Calculating Quantities
- Culvert Summary Frame
- Culvert Cover
- Approach Pipes
- Irrigation Pipes & Structures
- Hydraulic Details

Designers need to calculate Concrete Quantities for:

Inlet and Outlet Protection

*Hydraulics will now be specifying Concrete on both inlet and outlet ends – **no longer will be specifying Riprap**

Cutoff walls

CULVERT INSTALLATION QUANTITIES

DIAMETER OR SPAN x RISE	CUBIC YARDS OF CLASS GENERAL CONCRETE (EACH END) ④								CUBIC YARDS OF RIPRAP (EACH END) ① ④ (DTL. DWG. NO. 613-14)						C. Y. BEDDING MATERIAL ② PER FOOT OF PIPE (DTL. DWG. NO. 603-19)	
	CUTOFF WALL (DTL. DWG. NO. 552-00)		CONCRETE EDGE PROTECTION (DTL. DWG. NO. 613-06)													
			1.5:1		2:1		2.5:1		1.5:1		2:1		2.5:1			
	SING.	DBL.	SING.	DBL.	SING.	DBL.	SING.	DBL.	SING.	DBL.	SING.	DBL.	SING.	DBL.	SING.	DBL.
CSP 3" x 1" OR 5" x 1" CORRUGATIONS																
54"	1.2	2.0	2.1	3.0	2.5	3.6	2.9	4.3	8.3	13.3	10.3	16.5	12.5	20.1	0.9	1.8
60"	1.3	2.1	2.2	3.3	2.7	4.0	3.2	4.7	8.9	14.3	11.1	17.8	13.4	21.6	1.0	2.0
66"	1.3	2.2	2.4	3.6	2.9	4.3	3.5	5.1	9.6	15.4	11.9	19.1	14.3	23.1	1.0	2.1
72"	1.4	2.4	2.6	3.9	3.2	4.6	3.7	5.5	10.2	16.4	12.7	20.4	15.2	24.6	1.1	2.3

The Hydraulics Section will provide recommendations for special protection such as cutoff walls at both ends and concrete edge protection. *Hydraulics will now be specifying Concrete on both inlet and outlet ends.

Bedding Material

All pipes are bedded, no matter what the size.

Bedding quantities for Culvert installations less than or equal to 48” in

STATION	BASIC BID ITEMS					
		linear feet		cubic y		
	CULVERT PIPE in	LENGTH OF PIPE	REMOVE PIPE CULVERT	FOUNDATION MATERIAL	BEDDING MATERIAL Ω	GRANUALR BEDDING MATERIAL
524+60			41.0			
525+00	24	82				
538+70	36	104		65	70	

Ω FOR INFORMATION ONLY

SECTION 203, 207, 603, 701

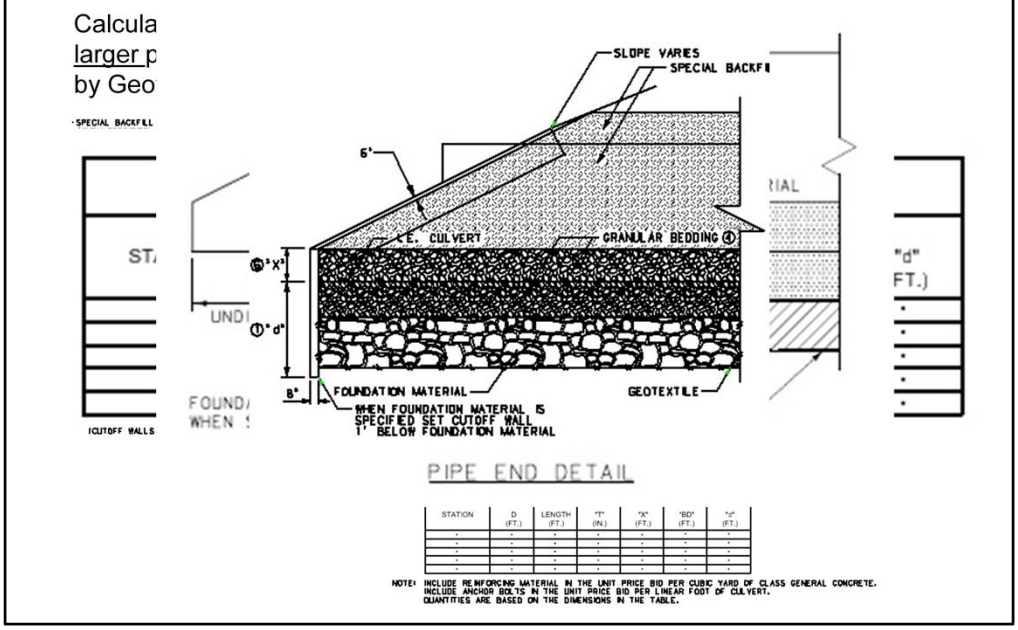
BEDDING FOR MAINLINE & PUBLIC APPROACH CULVERTS 48" (1200 mm) EQUIVALENT & SMALLER

EFFECTIVE: SEPTEMBER 2014

MDT MONTANA DEPARTMENT OF TRANSPORTATION

Bedding and Foundation material Quantities for 48” in diameter and less may need to be calculated if specified by Geotech or Hydraulics. If we have to calculate foundation material for for 48” in diameter and less, then we need to calculate bedding material and include it in the culvert summary frame and marked “For information Only”. This quantity needs to be in a column by itself.

Foundation Material and Granular Bedding



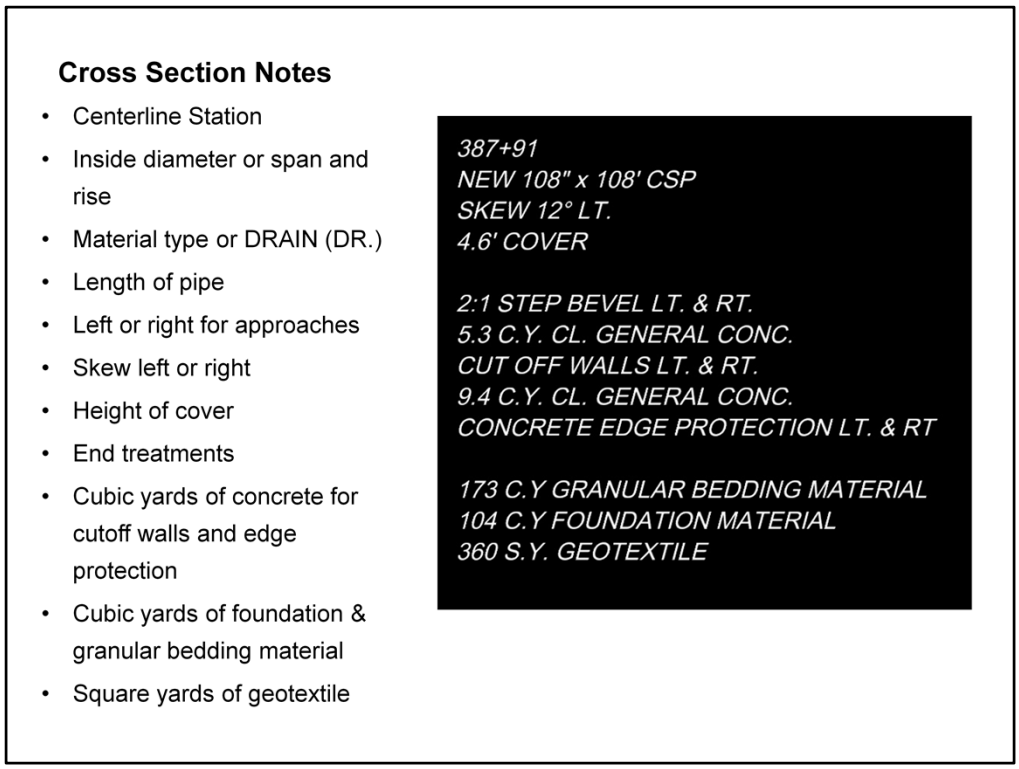
Calculate quantities for pipes 54” and greater. Calculate Foundation material if requested by Geotech.

The Compacted Bedding name has changed to Granular Bedding.

The cut-off wall height is based on Foundation Material needs.

No longer includes 10-foot of undisturbed material at pipe ends.

Hydraulics will no longer list quantities in their culvert details.



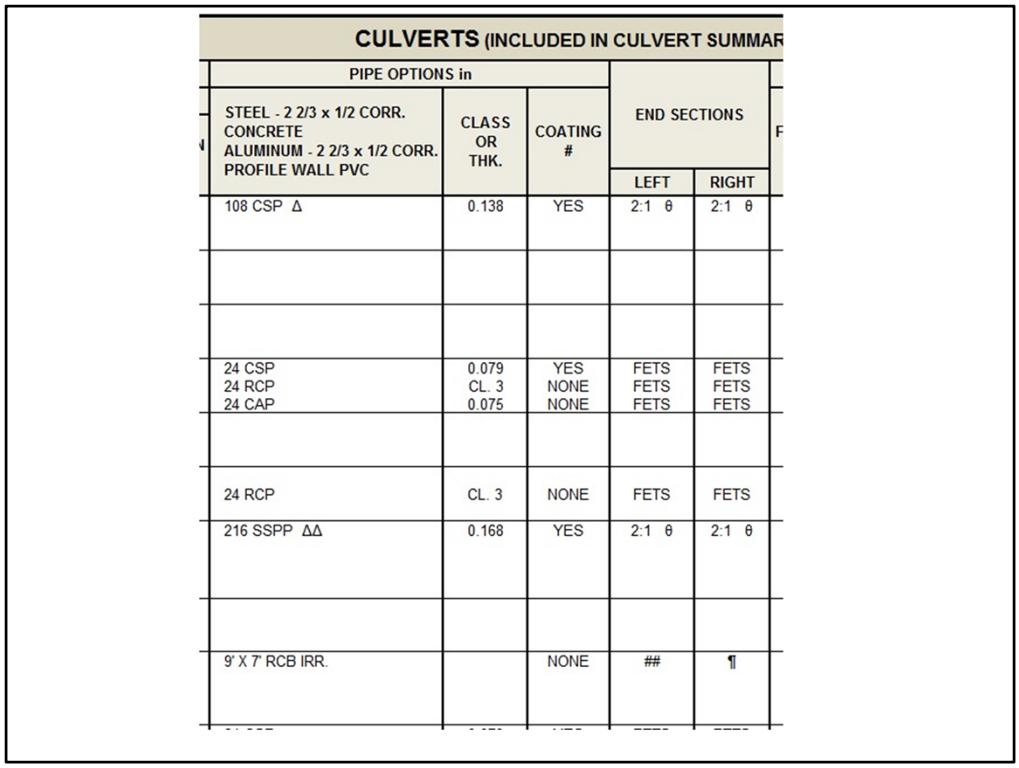
Now let's talk about placing notes in the cross sections. Place the notes on the right side of the cross sections. Include the centerline station rounded to the nearest foot, the inside diameter of the culvert or the rise and span, the material type or whether is a DRAIN or not, length of pipe rounded up to the nearest 2 foot increment, left or right for approaches, end treatments, skew left or right to the nearest degree, height of cover, cubic yards of foundation and bedding material, concrete & riprap, square yards of geotextile.

Culvert Summary Frame

STATION	BASIC BID ITEMS								
		linear feet		cubic yards					square yards
	CULVERT PIPE in	LENGTH OF PIPE	REMOVE PIPE CULVERT	FOUNDATION MATERIAL	GRANULAR BEDDING	SPECIAL BACKFILL	CONCRETE CLASS - GENERAL	RANDOM RIPRAP CLASS 1	STABILIZATION GEOTEXTILE
387+91	108	108		104	173		14.7		360
388+16			45.5						
406+69			49.1						
406+70	24	124							
418+00			61.0						
418+07	24	64							
425+88	216	172		294	630		28.9		960
589+70	24	98	88.9						
TOTAL	~	~	945.4	541	926	0	43.6	0.0	1,843

Let's break down the Culvert Summary Frame….. Station – nearest foot

- Culvert pipe size in inches
- Length of new pipe – 2 foot increments, except RCB come in 6 foot lengths
- Basic Bid items, such as Foundation, granular bedding, concrete, geotextile, etc.
- Round concrete to the nearest tenth of a foot.



CULVERTS (INCLUDED IN CULVERT SUMMAR

PIPE OPTIONS in STEEL - 2 2/3 x 1/2 CORR. CONCRETE ALUMINUM - 2 2/3 x 1/2 CORR. PROFILE WALL PVC	CLASS OR THK.	COATING #	END SECTIONS LEFT	END SECTIONS RIGHT	F
108 CSP Δ	0.138	YES	2:1 θ	2:1 θ	
24 CSP 24 RCP 24 CAP	0.079 CL. 3 0.075	YES NONE NONE	FETS FETS FETS	FETS FETS FETS	
24 RCP	CL. 3	NONE	FETS	FETS	
216 SSPP ΔΔ	0.168	YES	2:1 θ	2:1 θ	
9' X 7' RCB IRR.		NONE	##	¶	

- Pipe options with class, thickness and coating
- End Sections – included in length of new pipe for payment

linear feet HEIGHT OF COVER	SKEW ANGLE	CULVERT IN PL. in x ft	REMARKS
4.6	12° LT		CONCRETE CUTOFF WALLS AND EDGE PROTECTION AT INLET AND OUTLET
		36 X 45.5 RCP	
		18 X 49.1 RCP	
4.6	23° LT		DRAIN
		18 X 61.0 RCP	
1.2	15° LT		DRAIN
9.9	12° RT	57' TIMBER BRIDGE	CONCRETE CUTOFF WALLS AT INLET AND OUTLET, CONCRETE EDGE PROTECTION AT INLET & OUTLET, BACKFILL RETAINER AT OUTLET, SEE DET. DWG.

- Height of Cover – minimum measured at shoulder
- Skew angle – round to nearest degree
- Remarks such as DRAIN, IRR., Siphon, Broken-back, etc.
- If precast bends are necessary, indicate in the remarks column as well.
- What does it mean by DRAIN or DR.?

NOTE: Environmental would like to see the name of the crossing also listed in the REMARKS. This will help them in their permitting process.

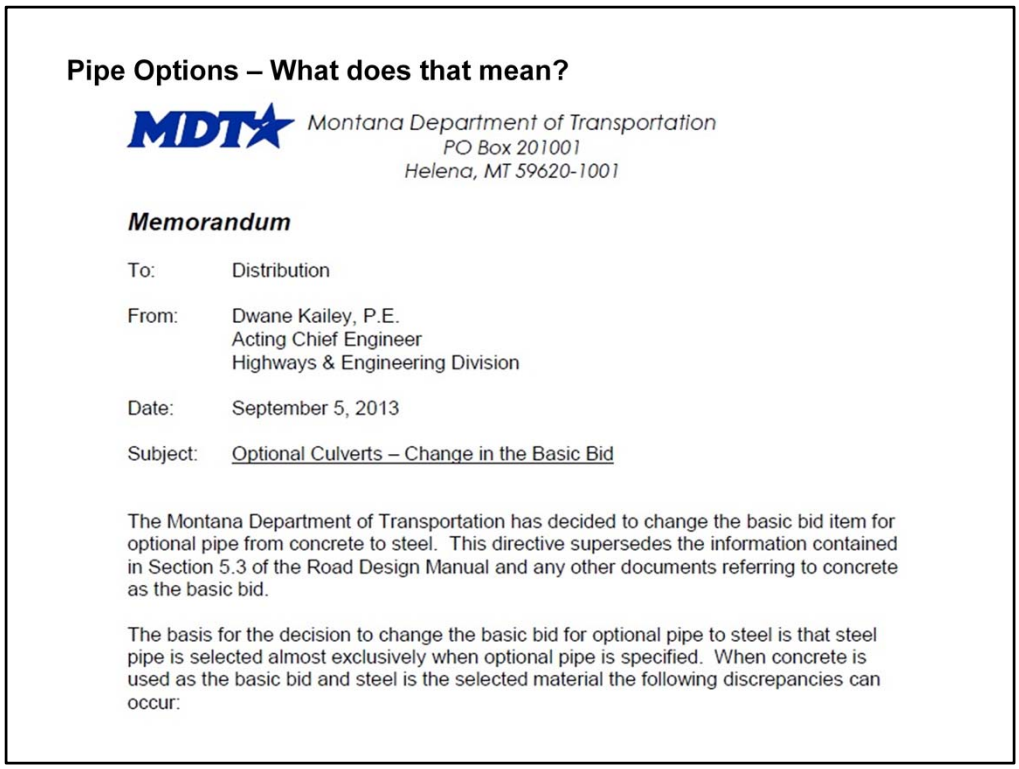
Pipe Options – What does that mean?

Will generally keep the cost of pipe down.

Not all locations are suitable for options.

Options shown on plans will more accurately represent what will actually be installed in almost all cases.

DRAIN means the pipe has options. In order to have options, the minimum cover requirements have to be met for all options.



Pipe Options – What does that mean?

Montana Department of Transportation
PO Box 201001
Helena, MT 59620-1001

Memorandum

To: Distribution

From: Dwane Kailey, P.E.
Acting Chief Engineer
Highways & Engineering Division

Date: September 5, 2013

Subject: Optional Culverts – Change in the Basic Bid

The Montana Department of Transportation has decided to change the basic bid item for optional pipe from concrete to steel. This directive supersedes the information contained in Section 5.3 of the Road Design Manual and any other documents referring to concrete as the basic bid.

The basis for the decision to change the basic bid for optional pipe to steel is that steel pipe is selected almost exclusively when optional pipe is specified. When concrete is used as the basic bid and steel is the selected material the following discrepancies can occur:

As per the memo that came out on September 5, 2013, the Basic Bid for optional culverts changed from concrete to steel.

Pipe Options – Still …… What does that mean?

the pipe size for the optional pipe (Drain) will be the size of the steel pipe

the quantities for the basic bid items will be for the steel pipe size

The size of pipes on the Plan/Profile & Cross Section sheets will be the size of the steel pipe.

CULVERTS (INCLUDED IN CULVERT SUMMARY RECAP)

PIPE OPTIONS in			END SECTIONS		
STEEL - 2 2/3 x 1/2 CORR. CONCRETE ALUMINUM - 2 2/3 x 1/2 CORR.	CLASS OR THK.	COATING #	LEFT	RIGHT	FO M
24 CSP	0.079	YES	FETS	FETS	
24 RCP	CL. 3	NONE	FETS	FETS	
24 CAP	0.075	NONE	FETS	FETS	
36 CSP	0.079	YES	FETS	FETS	
36 RCP	CL. 2	NONE	FETS	FETS	
36 CAP	0.075	NONE	FETS	FETS	

HDPE allowed on a case by case basis.

The order of pipe options will be steel, concrete and aluminum. Include Class or Thickness, coating and End treatment, left and right. HDPE is allowable for use on a case by case basis.

CULVERTS (INCLUDED IN CULVERT SUMI

BASIC BID ITEMS					PIPE OPTIONS in		
cubic yards				square yards			
FOUNDATION MATERIAL	BEDDING MATERIAL	SPECIAL BACKFILL	CONCRETE - CLASS GENERAL	STABILIZATION GEOTEXTILE	STEEL - 3 x 1 CORR CONCRETE ALUMINUM - 3 x 1 CORR.	CLASS OR THK.	COATING #
38	63		9.8	168	78" CSP 78" RCP	0.079 C L. 5	YES NONE
38	63	0	9.8	168	~	~	~

CULVERTS (INCLUDED IN CULVERT SUMMARY RECAP)

PIPE OPTIONS in			END SECTIONS		cubic yards			linear feet
STEEL - 3 x 1 CORR CONCRETE ALUMINUM - 3 x 1 CORR.	CLASS OR THK.	COATING #	LEFT	RIGHT	FOUNDATION MATERIAL	BEDDING MATERIAL	CONCRETE - CLASS GENERAL	HEIGHT OF COVER
78" CSP 78" RCP	0.079 C L. 5	YES NONE	2:1 STEP BEVEL FETS	2:1 STEP BEVEL FETS	38	73	9.8	2.1 1.5
~	~	~	~	~	~	~	~	~

Since the Basic bid item for optional pipe is steel, quantities are calculated based on the steel culvert size.

Quantities for the Base Bid Culvert (steel) will be included in the left columns.

When the pipe options are 54” & larger or an unique size, then calculate the foundation material, bedding, concrete & riprap quantities and include the quantities in the columns on the right side of the Pipe Options columns.

In this example, the difference between the options was the end treatment which resulted in the bedding material to be different. They will be listed for the concrete option on the right.

Culverts without options

CULVERTS (INCLUDED IN CULVERT SUMMAR

PIPE OPTIONS in			END SECTIONS		F
STEEL - 2 2/3 x 1/2 CORR. CONCRETE ALUMINUM - 2 2/3 x 1/2 CORR. PROFILE WALL PVC	CLASS OR THK.	COATING #	LEFT	RIGHT	
108 CSP Δ	0.138	YES	2:1 θ	2:1 θ	
24 CSP 24 RCP 24 CAP	0.079 CL. 3 0.075	YES NONE NONE	FETS FETS FETS	FETS FETS FETS	
24 RCP	CL. 3	NONE	FETS	FETS	
216 SSPP ΔΔ	0.168	YES	2:1 θ	2:1 θ	

If hydraulics specifies only one size or pipe material, then list only that size and material in the column. Include Class or Thickness, coating and End treatment, left and right.

Culvert Summary Recap

Total the lengths

STATION	BASIC BID ITEMS		PIPE OPTION
		linear feet	
	CULVERT PIPE in	LENGTH OF PIPE	STEEL - 2 2/3 x 1/2 CORR. CONCRETE ALUMINUM - 2 2/3 x 1/2 CORR. PROFILE WALL PVC
387+91	108	108	108 CSP Δ
388+16			
406+69			
408+15	24	124	24 CSP 24 RCP 24 CAP
418+00			
418+07	24	64	24 RCP
425+88	216	172	216 SSPP ΔΔ
426+89			
434+52	9' X 7' IRR.	78	9' X 7' RCB IRR.

Total up the lengths for each Drain steel option and

Culvert Summary Recap

DR. or DRAIN is acceptable

CULVERT SUMMARY RECAP

BASIC BID	NEW PIPE (TOTAL)
18" DR.	702
18" RCP CL. 4	536
18" PROFILE WALL PVC	170
24" DR.	1,130
24" RCP CL. 3	64
36" DR.	434
108" CSP x 0.138" THK. CTD.	108
9' x 7' RCB IRR.	78
216" SSPP x 0.168 THK. CTD	172
TOTAL	~

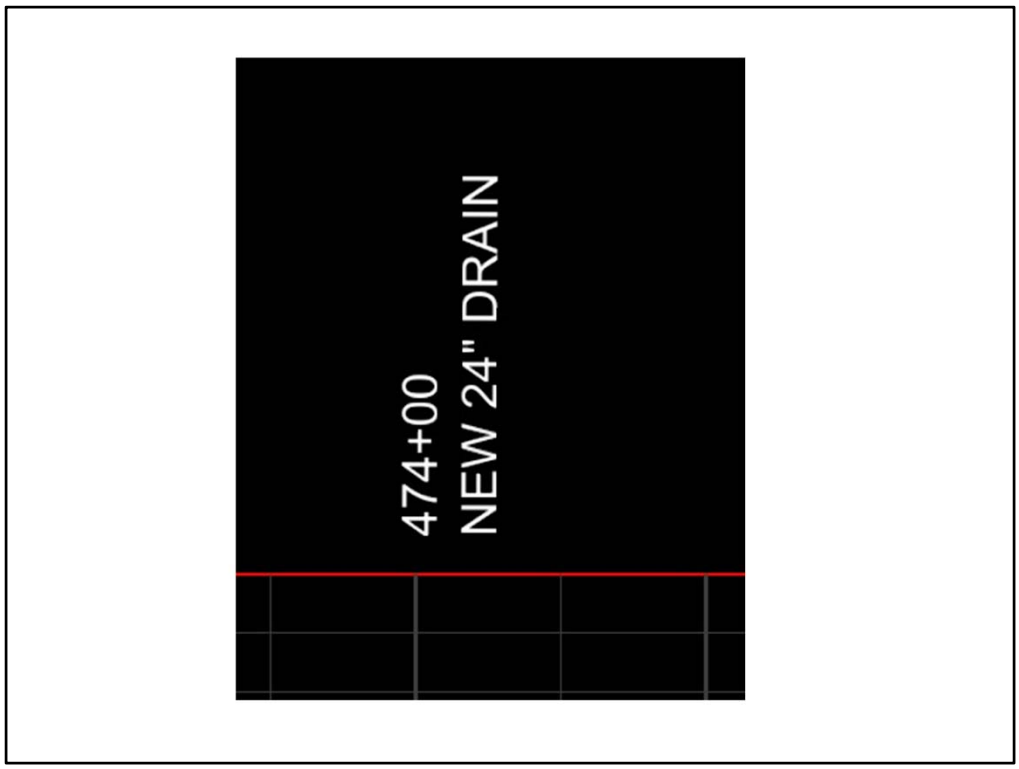
In the Culvert Summary Recap, the optional pipe (Drain) will be the size of the steel pipe.

Adding the word “DRAIN” has been accepted by the checkers which makes it clearer for the contractor.

The optional pipe will also be shown in the cost estimate as Drainage Pipe.

603010040	52	DRAINAGE PIPE 18 IN
603010048	1690	DRAINAGE PIPE 24 IN
603010056	357	DRAINAGE PIPE 30 IN
603010066	78	DRAINAGE PIPE 36 IN
603010176	74	DRAINAGE PIPE ARCH 51 IN
603010522	764	CSP 18 IN 0.064
603010532	50	CSP 24 IN 0.064
603010730	16	CSP 120 IN 0.138
603010955	42	CSPA 21 IN 0.064
603011148	74	CSPA 60 IN 0.079
603011720	16	SSPP 120 IN 0.109
603012610	120	RCP 30 IN CLASS 2

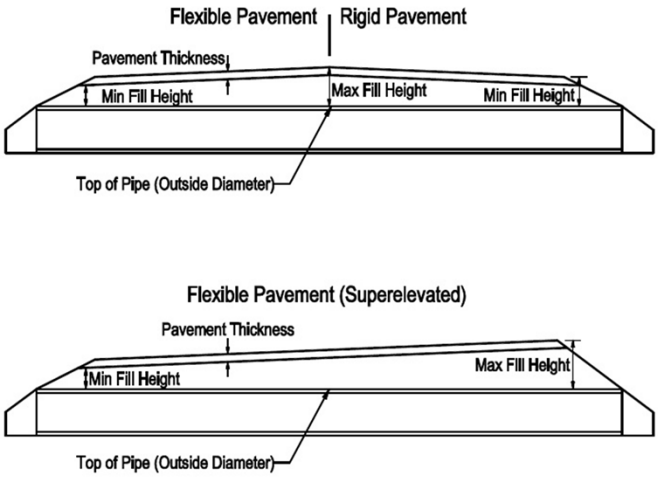
Use the bid number for Drainage Pipe



On the Plan & Profile sheets the pipe size for the optional pipe (Drain) will be the size of the steel pipe. It will be designated as DR. or DRAIN in the call out on the plan view.

In the cross sections, the steel pipe size and end treatment will be shown for the optional pipe (Drain). It will be designated as DR. or Drain in the notes.

Where do you measure the Height of Cover ?



Measure at lowest point of shoulder – top of subgrade (below PMS)
Superelevation – lowest point of super
Call out the minimum cover on the plans

Measure the cover at the lowest point of the finished grade, typically the shoulder. Measure from the top of the culvert to the top of the subgrade or to the bottom of the flexible (plant mix) pavement. If your roadway is on a superelevation, measure at the lowest point of the super.

Height of Cover (minimum)

The minimum cover controls the material of the pipe

2 ⅔" x ½" Corrugations ①, ② *Welded or Lock-Seam Steel Pipe*						
Pipe Diameter (in)	Minimum Fill Height* (in)	Maximum Fill Height* (ft) Metal Thickness (in)				
		0.064	0.079	0.109	0.138	0.168
12	18	213	266			
18	18	142	177			
24	18	106	133	186		
30	18	85	106	149		
36	18	71	88	124	159	
42	18	60	76	106	137	167
48	18	53	66	93	119	146
54	18		59	82	106	130
60	18			74	95	117
66	18				87	106
72	18				79	97
78	18					90
84	18					83

CSP Culverts have a minimum Fill Height of 18”

Let’s talk a little bit about the Height of Cover over mainline culverts. The cover called out in the plans should be the depth that controls the material type of the pipe. In most cases, the minimum cover is what controls the material of pipe.

CSP pipes have a minimum fill height of 18”.

Reinforced Concrete Pipes fill height varies by Class

Pipe Diameter (in)	RCP Minimum Fill Height* (in)			
	Pipe Class			
	Class 2	Class 3	Class 4	Class 5
12	**	**	12	6
18	**	18	6	6
24	**	12	6	6
30	24	6	6	6
36	6	6	6	6
42	6	6	6	6
48	6	6	6	6
>48	6	6	6	6

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement at the lowest point of the paved portion of the cross section.

** This class of pipe should not be used for the size noted for minimum cover designs.

If you have less than 18” in cover , than a concrete pipe is the next option. If you have a cover less than 18”, be sure to specify the Class of concrete in the summary table.

Approach Culverts

So now let’s talk about Approach Culverts

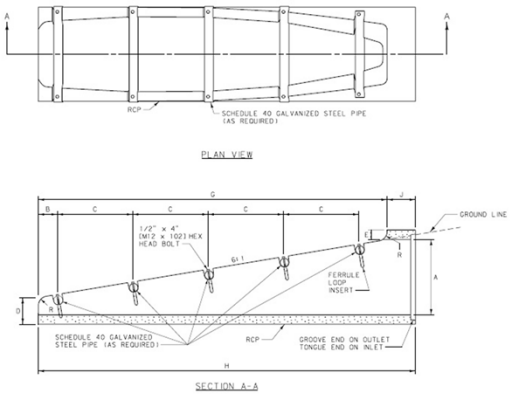
Road Approach Culverts

- No coatings
- At least 18” in diameter. Equivalent arch pipes may be used.
- Approach pipes located outside of our R/W can be whatever the owner wishes
- Outside the clear zone where practical.

- Approach pipes will not receive any coating unless specifically recommended.
- All new drainage approach culverts must be at least 18” in diameter. Equivalent arch pipes may be used.
- Approach pipes located outside of our R/W can be whatever the owner wishes
- Locate the entire road approach culvert including end treatment outside the clear zone where practical.

Road Approach Culverts

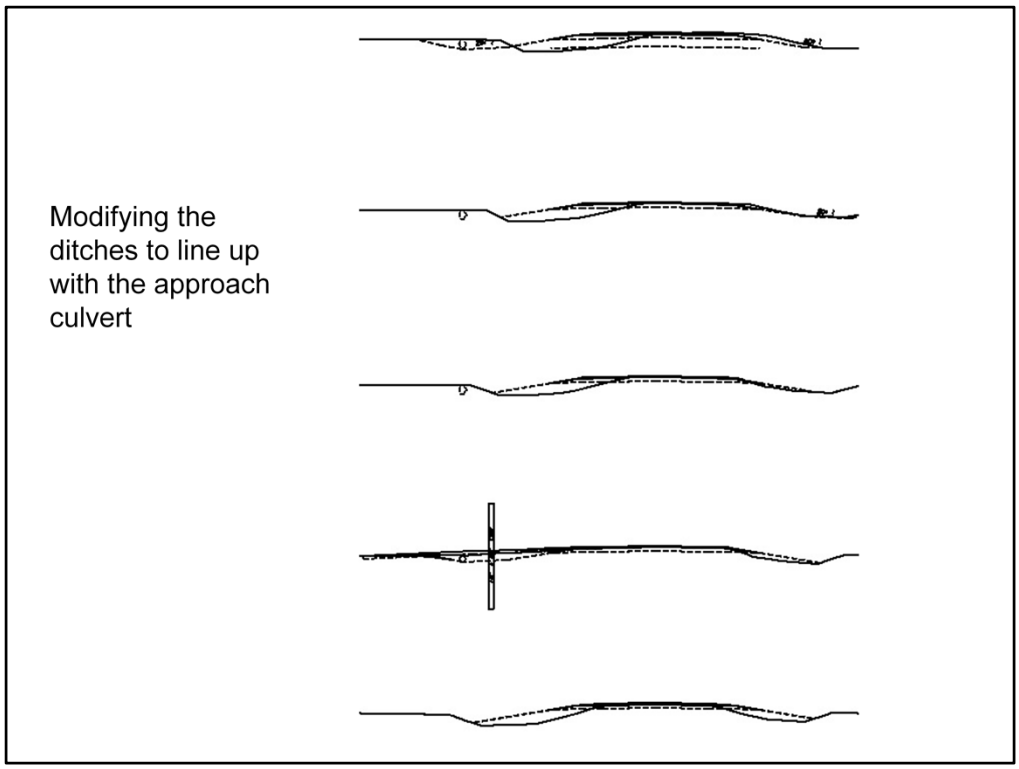
- FETS will be provided for all approach culverts located outside the clear zone.
- Where it is not practical to place approach culverts outside the clear zone, specify the 6:1 Road Approach Culvert End Treatment (RACET).



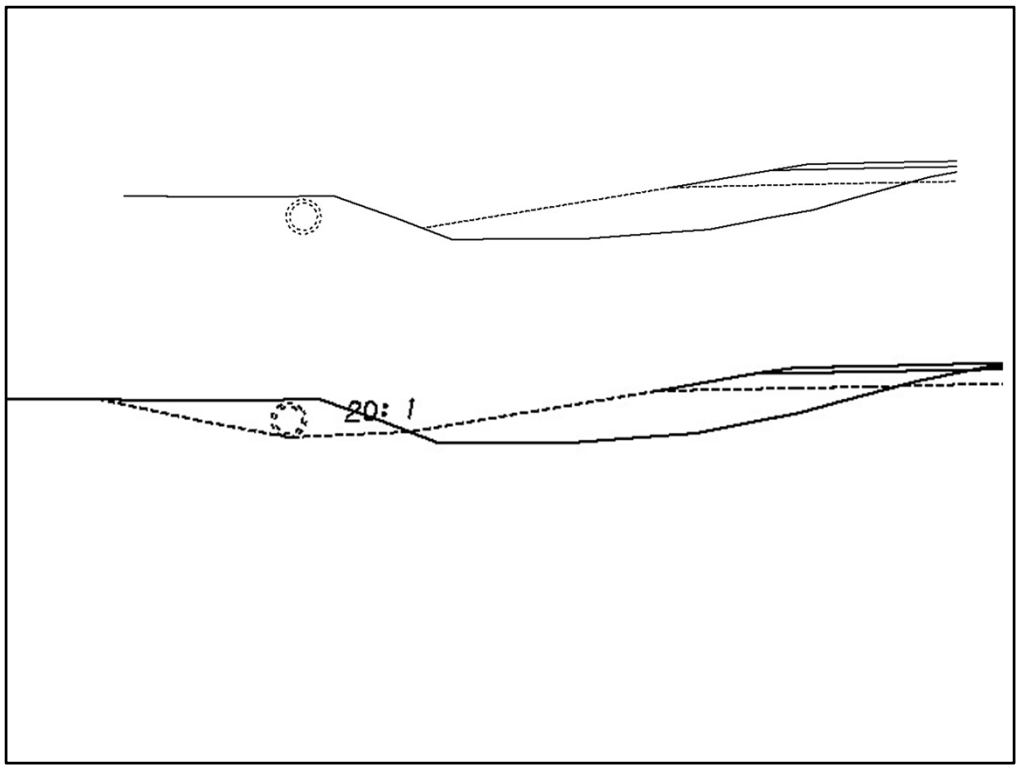
If you can locate the pipe out of the clear zone, then a RACET will need to be used.
CMP RACETs are are available for 15”, 18”, 24” and 30” diameters pipes.
RCP RACETs are available for 15”, 18” and 24” diameters pipes.

Place culvert so it lines up with the ditch upstream and downstream for positive flow.

May have to modify ditch to line up.



The next two stations ahead on line need to have their ditches modified so it lines up with the culvert and station back on line.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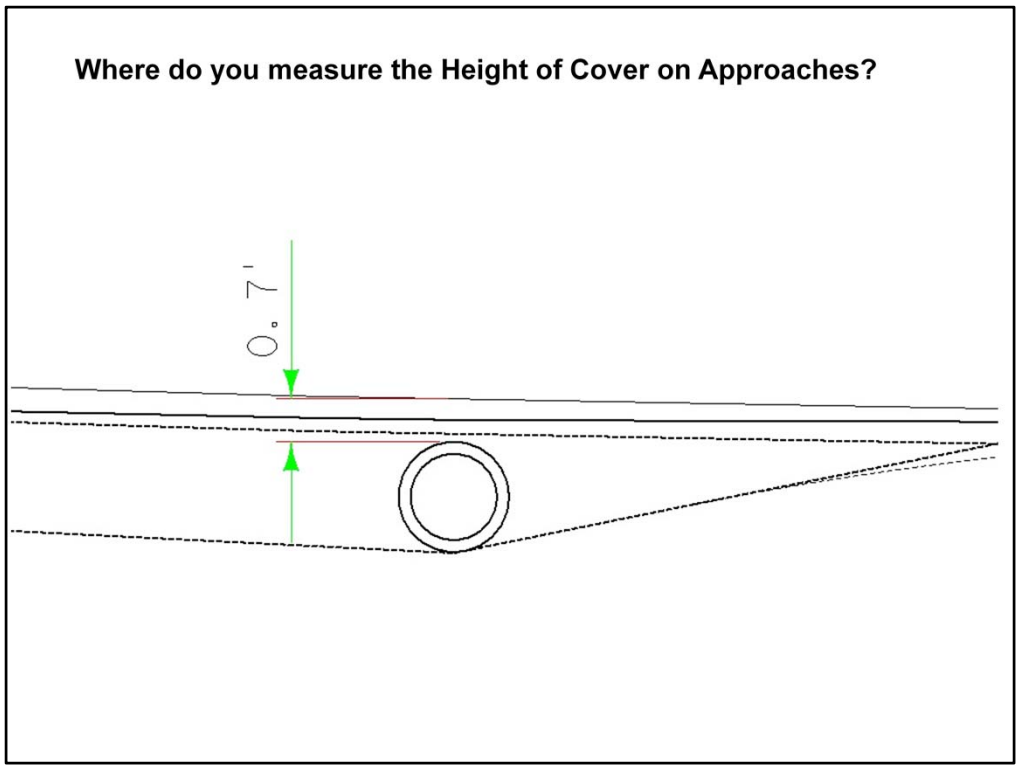


At approaches, measure the cover from the top of the pipe to the top of the subgrade or to the bottom of the flexible (plant mix) pavement. If you don't have plant mix, than measure to the top of the subgrade.

Approach Pipe Cover

Private Approach Pipes			
Pipe Size & Type	**Class of Pipe**	**Minimum Fill Height* (ft)**	**Maximum Fill Height* (ft)**
18" RCP	2	①	①
	3	1.5	15
	4	0.5	22
	5	0.5	33
18" CSP	--	1	142
18" CAP	--	1.5	75
18" HDPE	--	2	17

* Minimum fill height is measured from the top of the pipe to the top of the rigid pavement or to the bottom of the flexible (plant mix) pavement. Maximum fill height is measured from the top of the pipe to the point of maximum cover, including the total surfacing thickness.

Notes:

① Class 2 reinforced concrete pipe does not exist for 18" diameter pipe.

The Road Designer is responsible for selecting the correct material based on cover.

For approach culverts only, CSP pipes have a minimum height of 12". Otherwise, a concrete pipe is the next option. Based on the cover for a concrete pipe, be sure to specify the Class of concrete in the summary table.

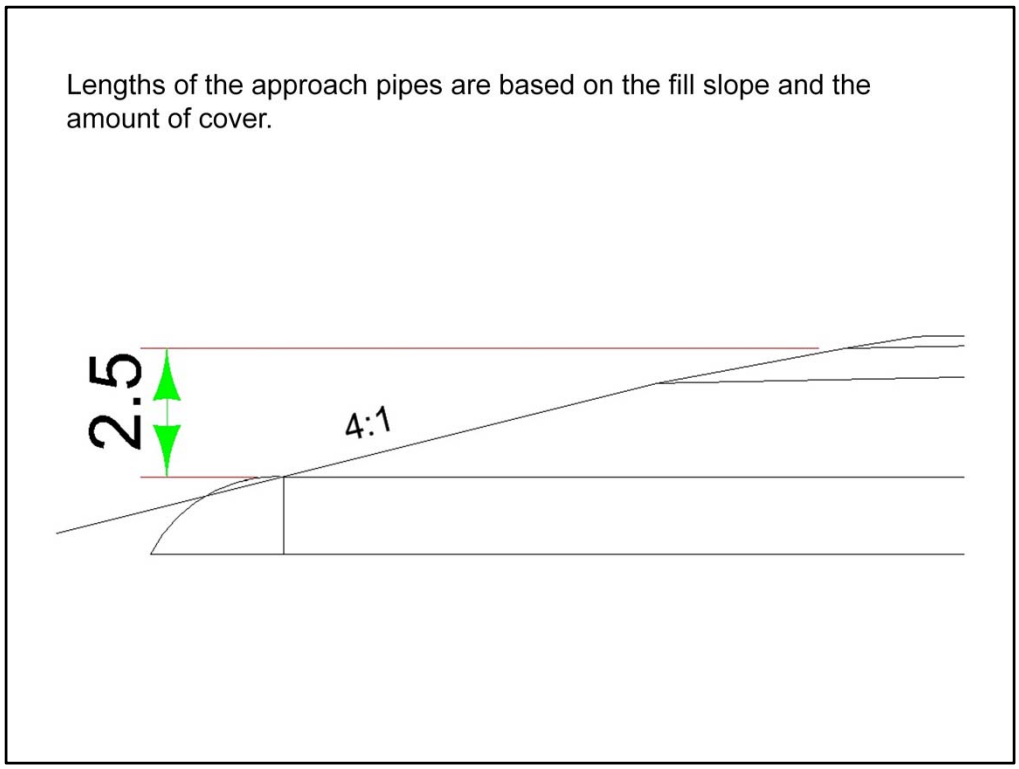
Approach pipes have options as well.

HDPE can be used but requires 24” minimum cover.

APPROACH PIPE (INCLUDED IN CULVERT SUMMARY RECAP)

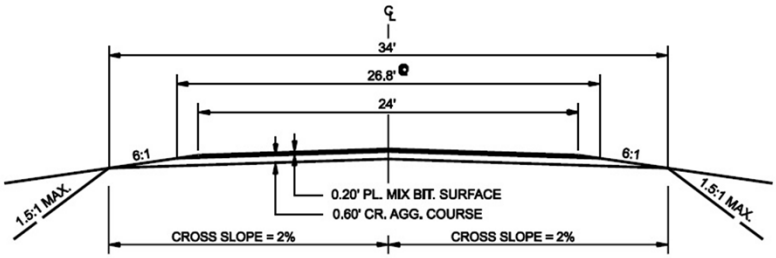
STATION	BASIC BID ITEMS				PIPE OPTIONS in				END SECTIONS		linear feet
	CULVERT PIPE in	linear feet			CONCRETE - CLASS 3	# STEEL - 2 2/3 x 1/2 CORR. 0.064 THK.	ALUMINIUM - 2 2/3 x 1/2 CORR. 0.060 THK.	CORRU-GATED POLY-ETHYLENE PIPE			HEIGHT OF COVER
		LENGTH OF PIPE	REMOVE PIPE CULVERT	RELAY CULVERT					LEFT	RIGHT	
342+82	18	38	64.1		18 CL. 4				FETS	FETS	0.5
342+82	18	38	24.2		18 CL. 4				FETS	FETS	0.5
371+90	18	52			18	18	18	18	FETS	FETS	2.2
372+04			24.4								
372+45	18	40	23.9		18 CL. 4				FETS	FETS	0.8
385+50	18	54	24.1		18	18	18	18	FETS	FETS	2.4
385+50	18	52	23.1		18	18	18	18	FETS	FETS	2.1
397+16	18	40			18 CL. 4				FETS	FETS	0.8
413+00	18	44	41.9		18 CL. 4				FETS	FETS	1.2
416+66	18	40	25.1		18 CL. 4				FETS	FETS	0.6
426+78	18	74			18	18	18	18	FETS	FETS	5.0
426+78	18	86			18	18	18	18	FETS	FETS	6.4
437+13	18	38			18 CL. 4				FETS	FETS	0.5
459+75	18	52	28.0		18	18	18	18	FETS	FETS	2.1
462+50	18	56			18	18	18	18	FETS	FETS	2.8

Approach pipes have options as well.
Approach pipes can be listed with options as long as they meet cover requirements for all options.
HDPE pipe requires 24” cover.

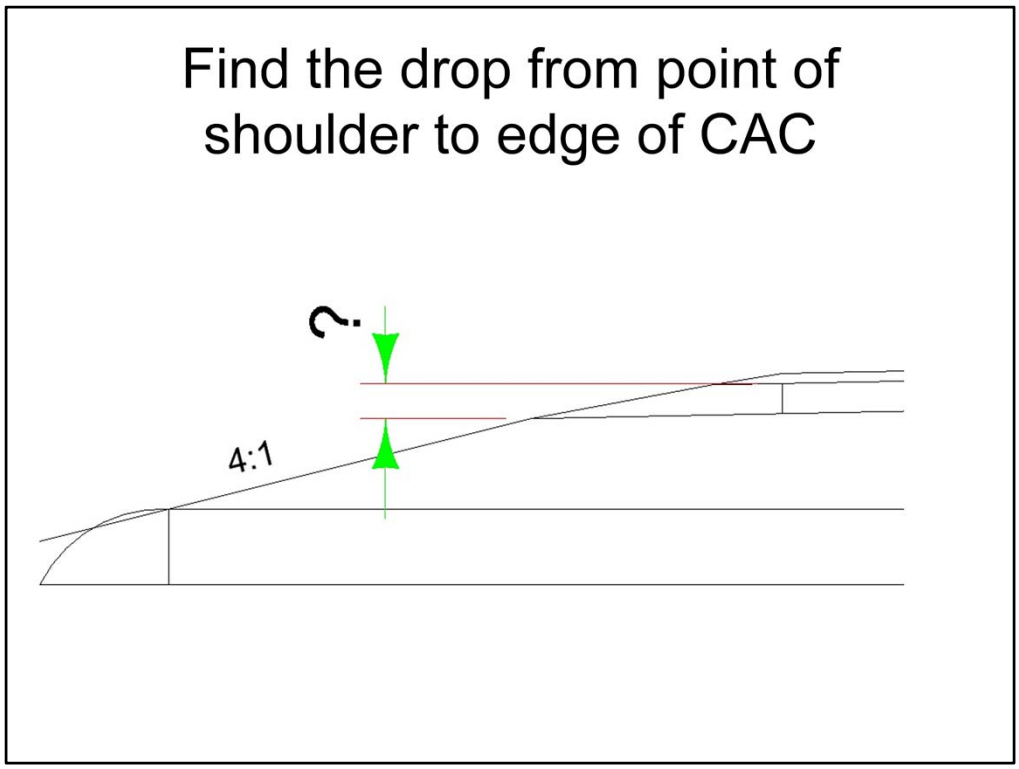


There have been jobs when there has been a shortage of 18” culvert pipe, due to miscalculation of approach pipe lengths.

Example of Pipe Length Calculation

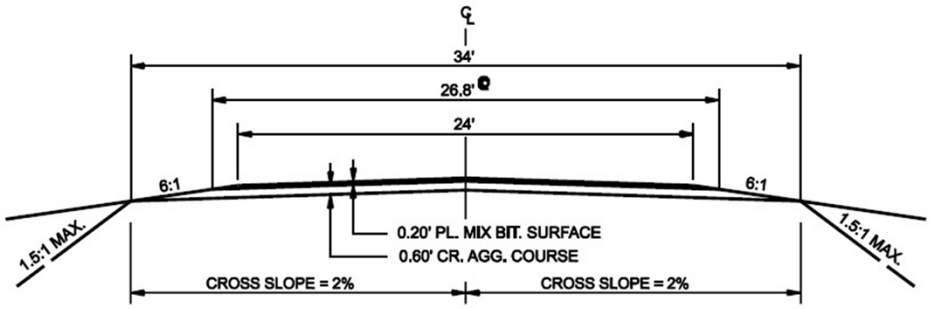


Given: Standard 24' approach
2.5 ft. of fill
0.60' CAC,
4:1 slopes at pipe
18" CSP
FETS on both ends



Since the cover is measured to the top of the subgrade at point of shoulder, we need to determine the drop from point of shoulder to edge of CAC at a 2% slope.

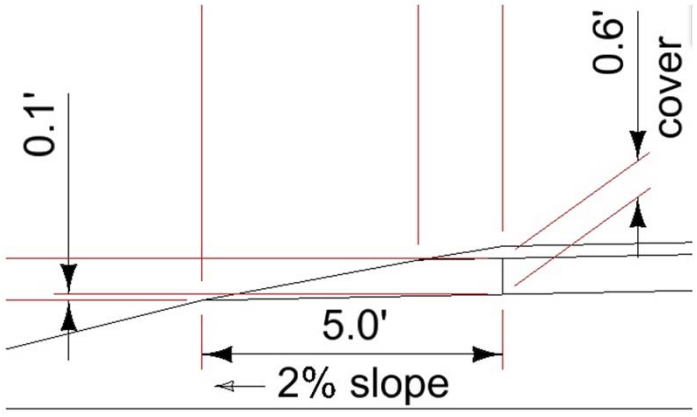
Find the difference in width



(34' - 24')/2 = 5' from edge of shoulder to edge of CAC

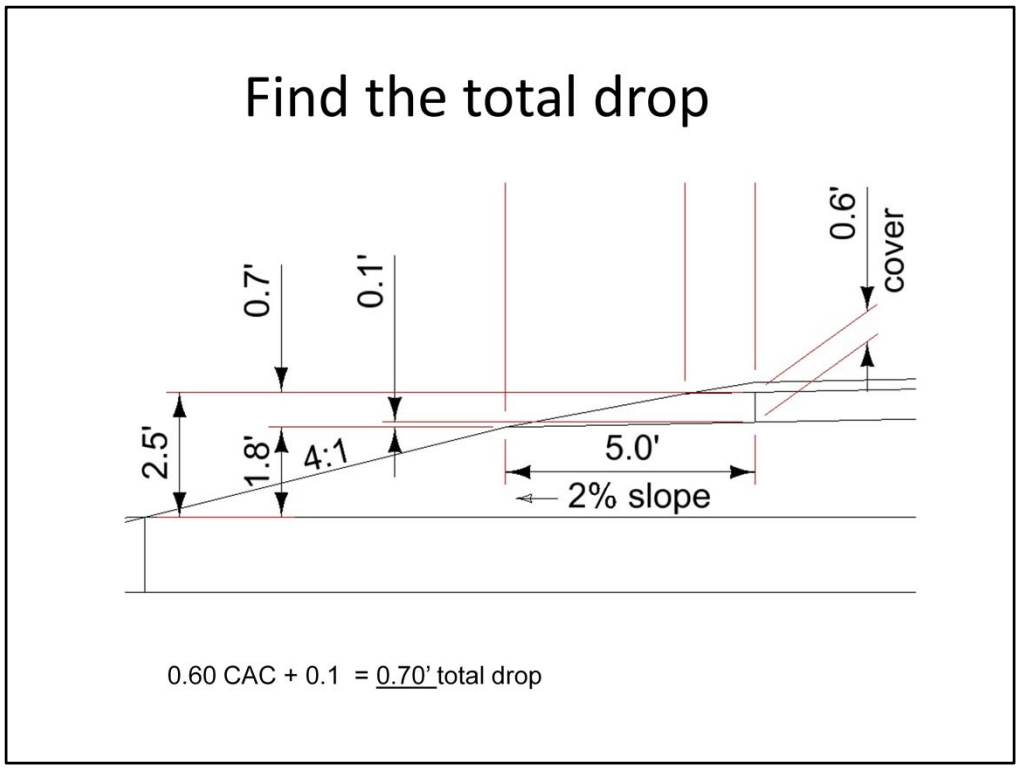
The first thing is to find the difference in width between the edge of the shoulder to the edge of the CAC.

Drop from shoulder to edge of CAC



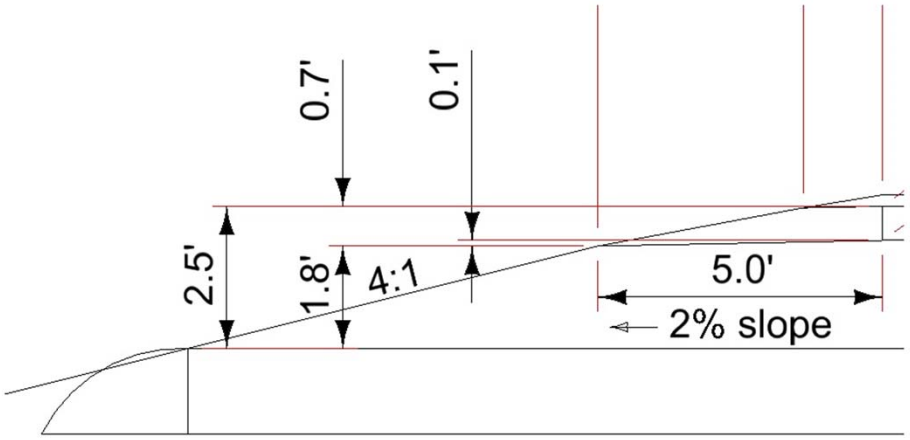
5' x 0.02 = 0.1' (drop)

Next we figure the drop from point of shoulder to edge of CAC .



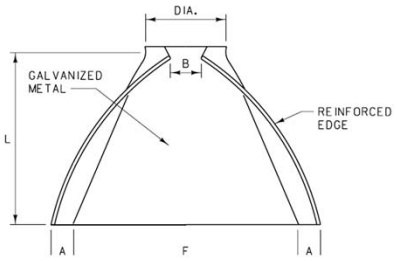
0.60’ CAC plus the new found drop of 0.1 = 0.70’ total drop

Subtract from the cover



Subtract 0.70' from cover to get cover at bottom of subgrade.
2.5' - 0.70' = 1.8' at a 4:1 slope

Length includes FETS



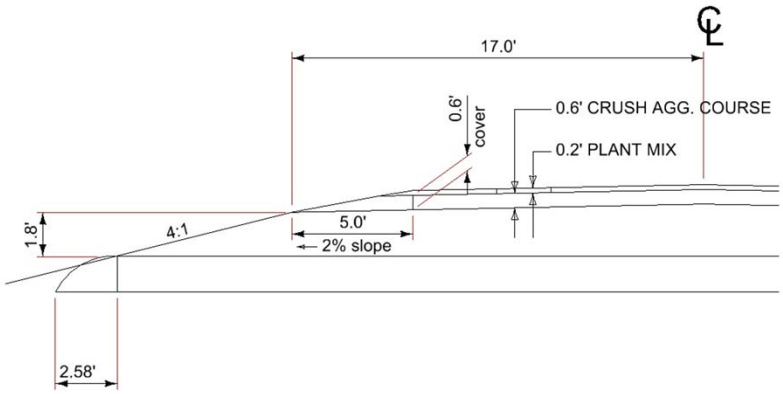
DIMENSION TABLE

PIPE DIA.	MINIMUM THICKNESS *	DIMENSIONS					TYPE CONNECTOR
		A 1" TOL.	B MAX.	H 1" TOL.	L 1 1/2" TOL.	F 2" TOL.	
12"	0.064"	6"	6"	6"	21"	24"	1
15"	0.064"	7"	8"	6"	26"	30"	1
18"	0.064"	8"	10"	6"	31"	36"	1
21"	0.064"	9"	12"	6"	36"	42"	1

For an 18" diameter CSP pipe, the FETS length is 31" = 2.58'

The approach pipe length includes the length of the end treatments (FETS).

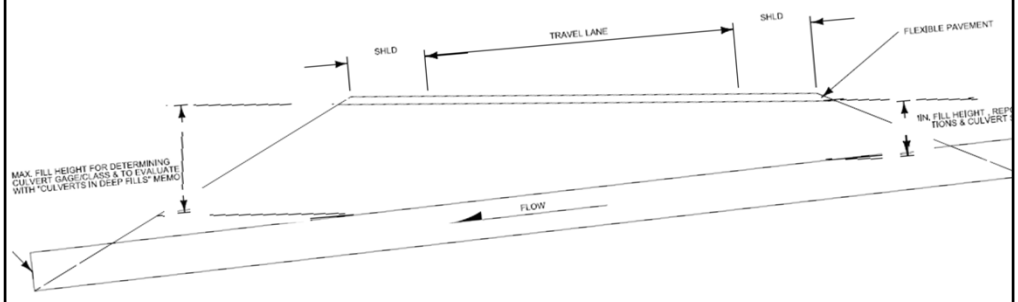
Final Length Calculation



Answer: (17' + (1.8' x 4) + 2.58') X 2
= 53.56' rounded up to even 2' incr. = 54'

This is just one way to solve for the lengths of approach pipe. Although the contractor is suppose to measure before they order the pipes, it is helpful if we can them an accurate length to go from in the first place. Does anyone have questions on that calculation?

Approach on steep profile grade



Calculate each end separately

The previous calculation was based on a cover equivalent on both ends of the pipe. If the approach pipe is following a ditch with significant grade, which affects the cover on both ends, then the calculation will need to be done for each end.

Irrigation pipes and structures

Irrigation Pipe:

- Require water-tight pipe.
- Identified as IRR. or Siphon in the Culvert Summary Frame.
- Aluminum and steel are typically <u>not</u> options
- Plastic irrigation pipe may be recommended by Hydraulics in some cases

STATION	CULVERT PIPE in	LENGTH OF PIPE
131+27	72 IRR.	296
131+72		
156+21	24 IRR.	92
157+33	18 IRR.	106
214+25	24 IRR.	110
256+29	36	638
256+45		
263+50	24 IRR.	74
279+58	24	58
279+58	24	58
280+88	24 SIPHON	142

What is the difference between Irrigation Pipe and standard culvert pipes?

Irrigation Pipe In the Summary Recap

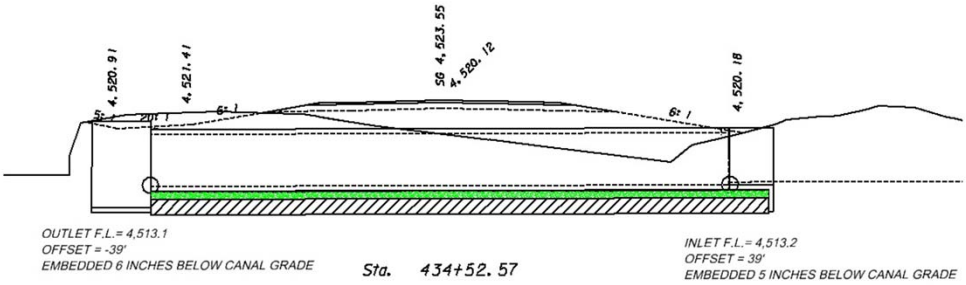
BASIC BID	NEW PIPE (TOTAL)
18" RCP IRR. CL. 3	106
24" DR.	172
24" RCP IRR. CL. 3	276
24" RCP SIPHON CL. 3	142
36" SM. STL. x 0.5 THK	638
72" RCP IRR. CL. 4000D	296

Irrigation Pipe in the Summary Recap

Irrigation Pipes in the Cross Sections will have:

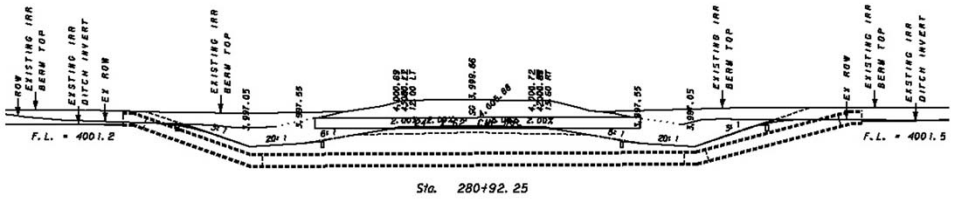
- flowline and pipe invert elevations provided by the Hydraulics Section
- Irrigation pipe end stations and offsets

- All pipes larger than 54” should show the foundation and granular bedding material in the cross section



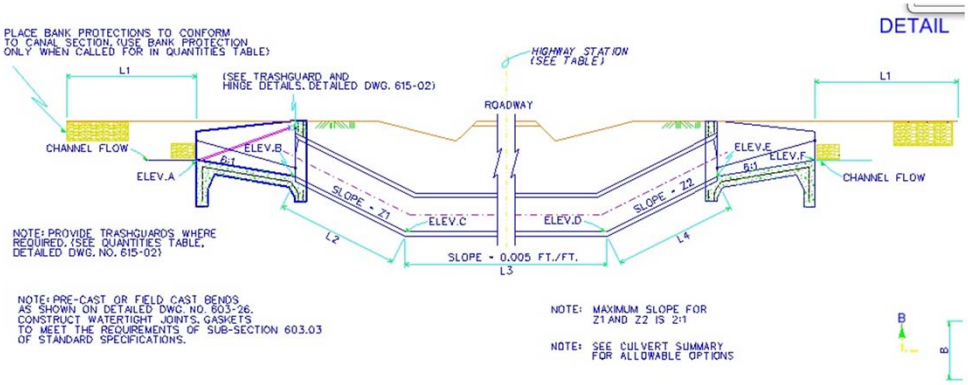
Irrigation Siphon Pipe

- call out on plan sheets
- Only show invert and outlet elevations in the cross sections.
- Include “See Detail” note.



Irrigation Siphon Pipe

Hydraulics will provide a detail sheet



Channel Changes and Ditch Relocations

Hydraulic details are currently showing….

CHANNEL CHANGE QUANTITIES - 388+05 TO 389+05 & 391+30 TO 392+80							
CHANNEL EXCAVATION (yd³)	COIR NETTING (yd²)	12" COIR LOGS (ft)	SALVAGEABLE STREAMBED MATERIAL ** (yd³)	STREAMBED MATERIAL (yd³)	WETLAND SOIL ## (yd²)	NATIVE FILL MATERIAL # (yd³)	WILLOW CUTTINGS * (each)
1175	1735	810	35	26	150	135	405

INCLUDED IN THE COST PER CUBIC YARD OF UNCLASSIFIED CHANNEL-EXCAVATION.
INCLUDED IN THE COST PER CUBIC YARD OF WETLAND SOIL- SALVAGE AND PLACE.
* FOR INFORMATIONAL PURPOSES ONLY. WILLOW CUTTINGS PAID FOR AS LUMP SUM. SEE SPECIAL PROVISIONS.
** INCLUDED IN THE COST PER CUBIC YARD OF STREAMBED MATERIAL.

Note how different items are being paid for

In the future these quantities may be eliminated from their details

Irrigation and drainage channel changes have their own summary frame. Pay attention to how items are being paid for.

Channel Changes and Ditch Relocations

Summary Frame – Irrigation & Drainage Channel Changes

IRRIGATION & DRAINAGE CHANNEL CHANGES *

STATION		LT./RT.	cubic yards						square y
FROM	TO		UNCLASSIFIED EXCAVATION - CHANNEL	WETLAND SOIL - SALVAGE AND PLACE	STREAMBED MATERIAL	SALVAGEABLE STREAMBED MATERIAL #	NATIVE FILL MATERIAL ##	SPECIAL EMBANKMENT	EROSION CONTROL BLANKET-SHORT TERM
388+05	389+05	RT.	432	55	10	13	50		
391+30	392+80	RT.	743	95	16	22	85		
425+70	425+58	RT.	630						750
434+50	437+44	RT.	2,800					2,470	1,422
440+35	466+85	RT.	6,360					70	
461+39	462+63	RT.	15					160	
461+42	466+00	RT.						175	
462+76	464+63	RT.	30					50	
466+08	466+70	RT.	20						
529+96	531+96	RT.	810					420	
563+50	576+45	RT.	1,770					270	
580+16	587+10	RT.	510					875	
TOTAL		~	14,120	150	26	35 #	135 ##	4,490	2,172

* SEE SPECIAL PROVISIONS AND DETAILS
# INCLUDED IN THE COST PER CUBIC YARD OF STREAMBED MATERIAL. FOR INFORMATION ONLY.
INCLUDED IN THE COST PER CUBIC YARD OF UNCLASSIFIED EXCAVATION - CHANNEL. FOR INFORMATION ONLY.

……that may include unclassified excavation – channel, wetland soil-salvage and place, streambed material, native fill material, special embankment and erosion control quantities.

* SEE SPECIAL PROVISIONS AND DETAILS
# INCLUDED IN THE COST PER CUBIC YARD OF STREAMBED MATERIAL. FOR INFORMATION ONLY.
INCLUDED IN THE COST PER CUBIC YARD OF UNCLASSIFIED EXCAVATION - CHANNEL. FOR INFORMATION ONLY.

Irrigation Facilities

Summary Frame – Irrigation Structures

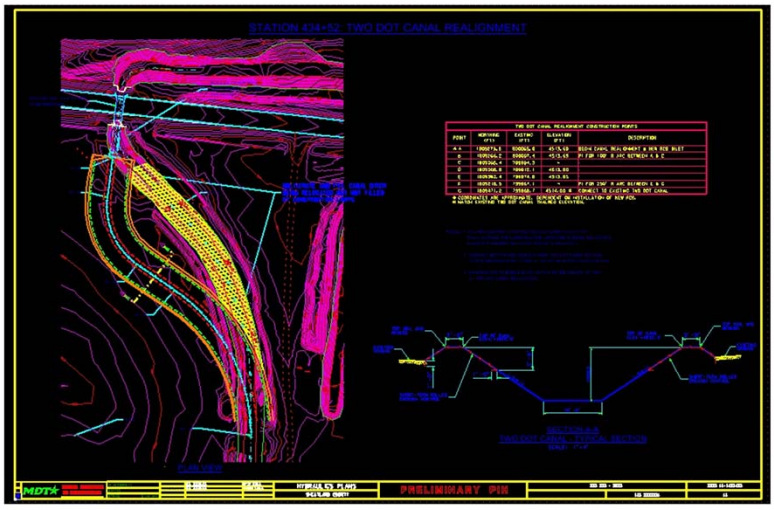
IRRIGATION STRUCTURES										
		cubic yards		square yards	lbs.	lump sum	each			
STATION	LT./RT.	CONCRETE CLASS - GENERAL	RANDOM RIPRAP	GEOTEXTILE PERM. EROS. CONTROL HIGH SURV. CLASS C	#4 REBAR *	IRRIGATION STRUCTURE	IRRIGATION DIVISION BOX	STEEL FLUME	REMOVE IRRIGATION STRUCTURE	TYPE OF STRUCTURE
			CL. 1				TYPE 3			
434+52									1	EXISTING DOUBLE 4X3 RCB IRR.
434+52	RT.	7.5			382					FLAT BOTTOM CONCRETE TRANSITION STRUCT
461+30	RT.	3.7	5.3	15	220	1				PIPE OUTLET STRUCTURE
461+73	RT.		2.2	7				1		STEEL REPLOGLE FLUME - I.E. 4497.5
461+77	RT.								1	EXISTING STEEL FLUME
462+27	RT.								1	18" X 14.2 CMP/IRR. W/SLIDE GATE
462+29	RT.								1	18" X 19.4 CMP/IRR.
462+35	RT.						1			IRRIGATION DIVISION BOX , B=2.5 FT. , F.L. = 44
462+38	RT.								1	18" X 15.1 CMP/IRR. W/SLIDE GATE
462+56	RT.								1	18" X 12.8 CMP/IRR. W/SLIDE GATE
462+61	RT.								1	18" X 15.0 CMP/IRR. W/SLIDE GATE
462+62	RT.								1	18" X 15.9 CMP/IRR. W/SLIDE GATE
462+70	RT.						1			IRRIGATION DIVISION BOX , B=2.5 FT. , F.L. = 44
466+08	RT.						1			IRRIGATION DIVISION BOX , B=2.5 FT. , F.L. = 44
TOTAL	~	11.2	7.5	22	602	1	3	1	8	

* FOR INFORMATION ONLY. INCLUDE IN THE COST OF CONCRETE CLASS GENERAL.

Include quantities for irrigation structures in a separate summary frame that may include class general concrete, riprap, rebar, irrigation structure, division boxes, steel flume and remove irrigation structure.

Reinforced Concrete Boxes are shown in the Culvert Summary frame. The Flat Bottom concrete transition structure is paid for in this box.

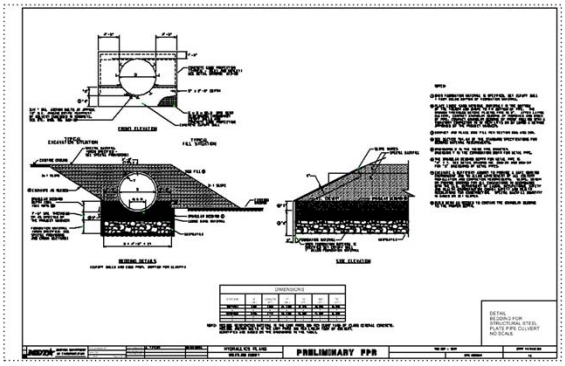
Hydraulic Details



Now we will cover incorporating Hydraulic Details into our plan set.

Hydraulic Details

- Structural steel plate pipe culverts
- irrigation facilities
- reinforced concrete boxes
- other large culverts
- channel and canal changes
- and other special hydraulic features designed and detailed by the Hydraulics Section
- Hydraulic Data Summary Sheet

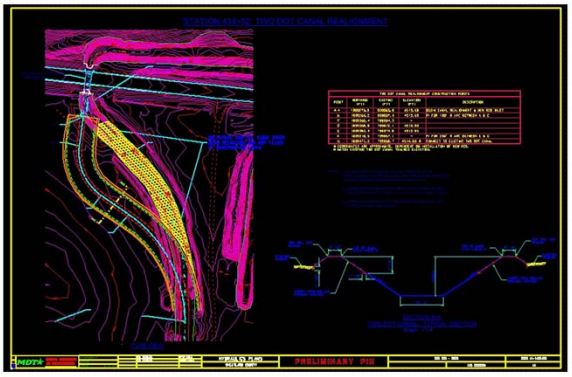


Some type of Hydraulic Details you may need to add to the plan set include:

Hydraulic Details

Road Design section is responsible for including the Hydraulic details in the Road Design CPB file or book.

A copy of the Hydraulic Cadd files need to be included in the Road Design directory on DMS.

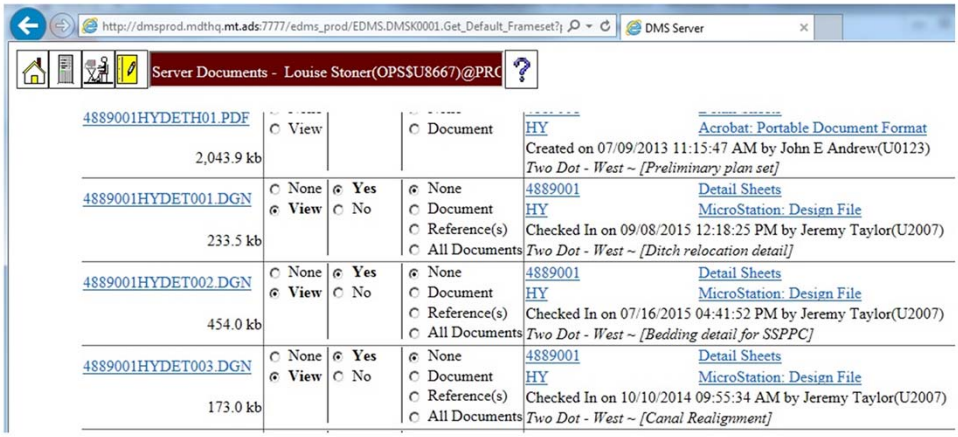


Since the Hydraulics Section does not create their own CPB file for plotting the final plans, the Road Design section is responsible for including the Hydraulic details in the Road Design CPB file.

In order for Road Design to include the Hydraulic details in the Road Design CPB file, a copy of the Hydraulic Cadd files need to be included in the Road Design directory on DMS.

This can be accomplished by doing the following steps:

1. Download a View copy of the Hydraulic CADD detail from DMS



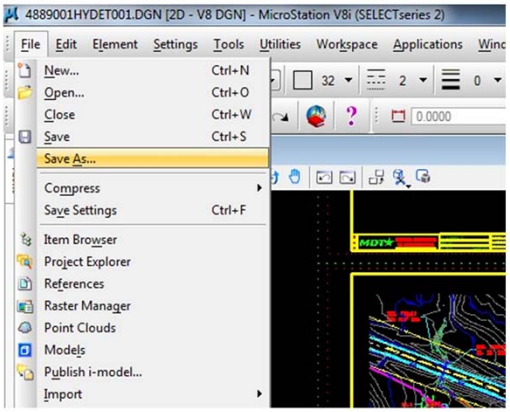
Download a View copy of the Hydraulic CADD detail from DMS. Typically the Hydraulic's Recommendation report will tell you which files contain the details.

2. Open the file just VIEWED

3. SAVE AS and Rename the file to the Road Design area

Example:

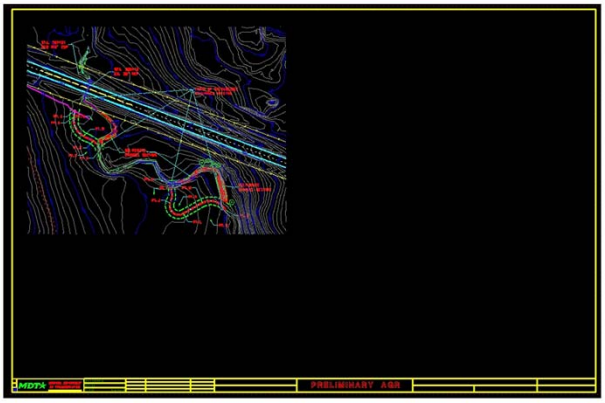
4889001HYDET001.DGN
to
4889001RDDETHY1.DGN



Open the Hydraulic CADD file just VIEWED
Perform a SAVE AS and Rename the file to the Road Design area
To help keep hydraulic detail files separate from Road Design details, name the file with HY1 in the last 3 digits of the file name.

4. Make a plot of the file

5. Turn on all levels and delete all elements in the file



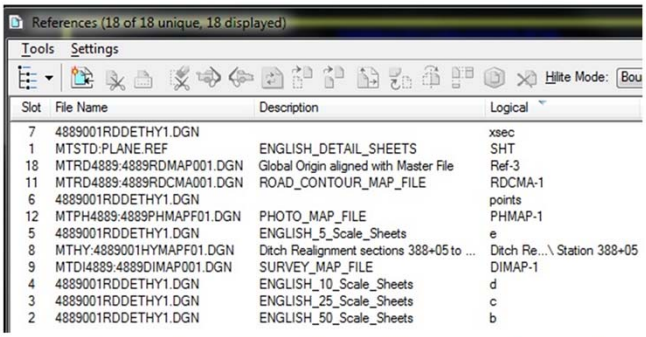
Hint: Before deleting all of the elements in the file, make a plot of the detail sheet to compare to when finished.

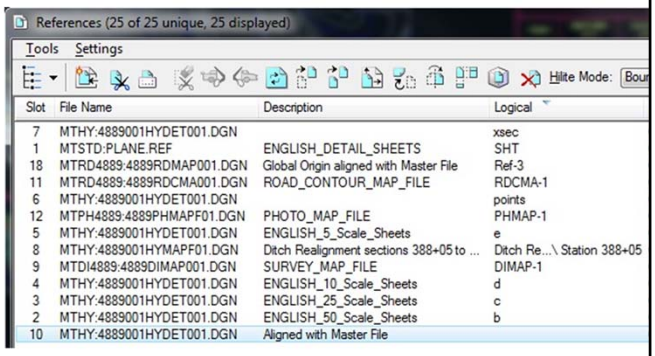
This example to the right shows a reference file from the Road map file is attached. Leave all reference files currently attached to the file.

*You may need to coincidentally reference the Hydraulic CADD detail file to include any notes or title call outs that are included in the sheet view. We encourage the Hydraulic Engineers to include all notes as part of their reference file instead of putting the notes in the detail sheet.

**Also, if the Hydraulic section modifies the locations of the reference files or adds new reference files to their sheets, please notify the Road Designer so they can update their detail file.

5. Rename the reference file to the original Hydraulics file name, using the MTHY: prefix



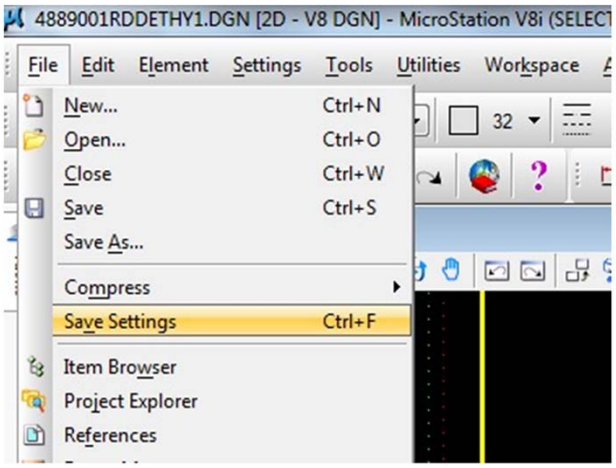


When you create the new file using the SAVE-AS function, it will automatically name the reference files with the name of the newly created file as shown to the right.

5. Rename the reference file to the original Hydraulics file name, using the MTHY prefix path to obtain the file from DMS.

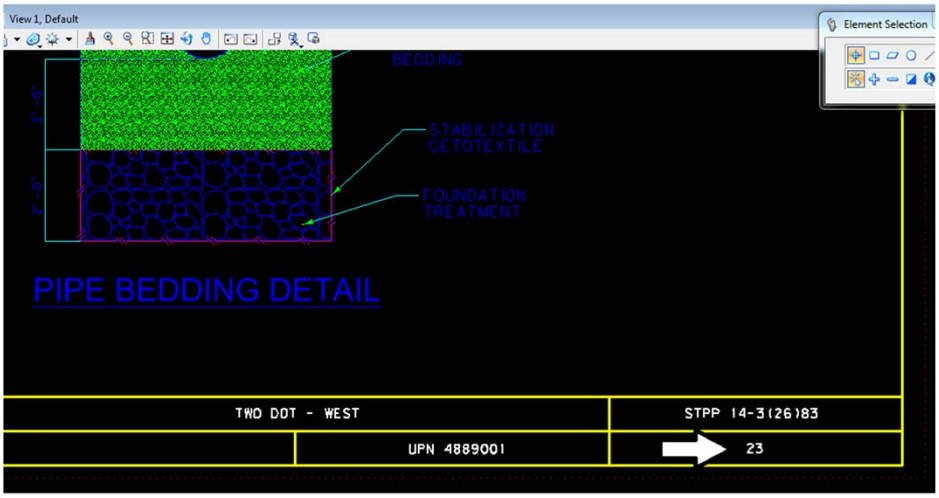
In this example an additional reference file was attached coincidentally to include the detail titles and notes

6. Save Settings



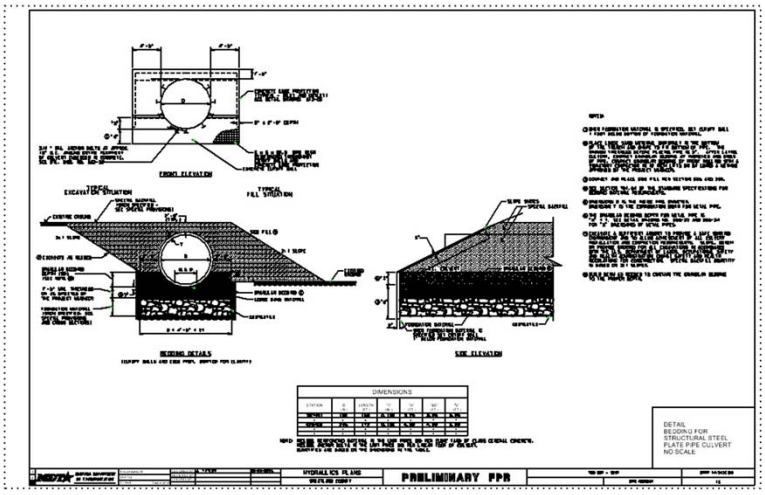
Perform a Save Settings to retain the reference file name changes

7. Add the appropriate sheet number.



The only active element in this file will be the sheet number.
Everything else is referenced into the file.

8. Plot the newly created Road Design version of the detail

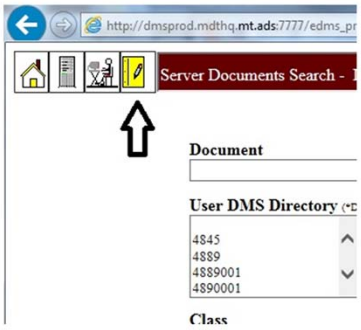


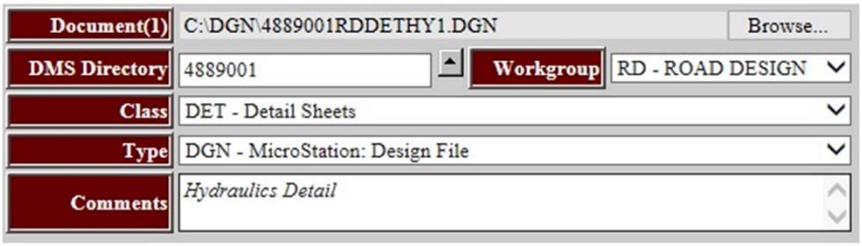
Compare with original

- Verify correct levels are turned on
- All of the notes and details are included

Plot and compare to make sure all of the correct levels, notes and details are displaying.

9. Finally - Place the newly created file on DMS using the Create Document tool.





This procedure should eliminate problems associated with referencing and retaining any level symbology & gray scaling included in the CADD file created by the Hydraulics Section.

Summary – Part One

Existing Pipes
- Determining lengths, locations and sizes and accurately placing them in plans

Drainage
- Sustained grades, cut to fill transitions and various ditches and how to modify the cross sections to maintain positive flow and provide erosion protection

New Pipes
- Hydraulic Recommendation Reports, placing in Plan/Profile sheets, Cross sections and summary frames
- Calculating lengths and using Geopak tools to determine stations and offsets

Clear Zones
- Concrete edge protection
- Special guards on pipes in the clear zone
- RACETs on approach pipes

Summary – Part Two

Culvert Summary Frame
- Rounding, pipe options and basic bid items

Measuring cover and using that to determine pipe material

Approach Pipes
- Aligning ditches for better flow
- Calculating lengths based on cover

Irrigation Facilities
- Labeling as IRR. and Siphons
- Including elevations, stations and offsets provided by Hydraulics
- Unique summary frames
  - Irrigation & Drainage Channel Changes
  - Irrigation Structures

Hydraulic Details
- Incorporating them into our Contract Plans Book (CPB)

MISSION

MDT's mission is to serve the public by providing a transportation system and services that emphasize **quality**, **safety**, **cost effectiveness**, **economic vitality**, and **sensitivity to the environment**.

As Designers, we need to do our best when preparing designs and plans.

We need to design our drainage ditches and place culverts and erosion control devices in a safe, cost effective manner, while being sensitive to the environment.

Our plans need to be complete and accurate to avoid confusion and costly change orders.

Questions?

If you would like a copy of the power point and/or you have questions: Contact Information

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